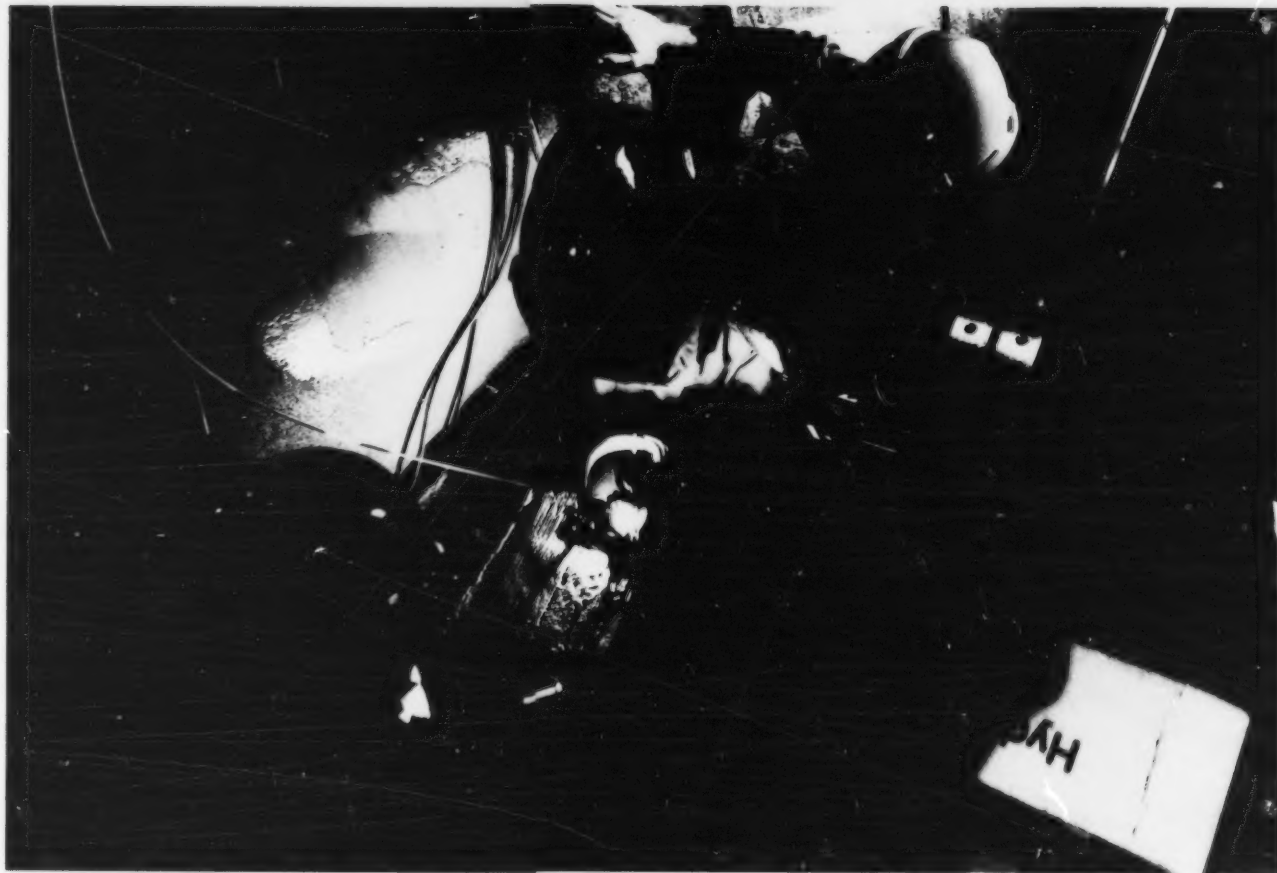


ONTARIO HYDRO
RESEARCH ANNUAL



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Technological insurance is that scientific
and engineering expertise, which,
through research, development, problem
solving, and testing, assures the most
efficient, safe, and reliable power
system for Ontario, now
and in the future.

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VICE PRESIDENT'S MESSAGE

Al Holt, Vice President of Corporate Planning Branch, Don Mills, Director of Research Division, and Harry Kirwin, Station Manager of Nanticoke TGS discuss the optimization of generator performance and reliability.



The 1990s promise to be very challenging for Ontario Hydro. The new problems confronting the Corporation – ensuring that Ontario's rapidly growing electrical demand will be met over the next 25 years, and doing this in an environmentally acceptable way – will create new challenges for the Research Division.

The Division must continue to help Ontario Hydro fulfil its traditional role of providing safe, reliable, electricity for the people of this province. It must also play an increasingly important role in minimizing the impact of Hydro's activities on the environment.

During the past year, system demand reached an all-time high; the Corporation published its 25-year plan, the most far-reaching in its history; and the first steps to transform Ontario Hydro into a fundamentally service-oriented corporation were taken.

The 25-year plan proposes a number of options for meeting power system requirements. Regardless of which option is selected, it will be necessary to maintain and enhance the performance of existing plant as well as to utilize new technologies. The Research Division has a very important role to play in support of these objectives.

To get more out of its existing facilities, Ontario Hydro will have to expand its anticipatory approach to maintenance and aggressive life extension efforts. Products like the Partial Discharge Analyzer and machine vibration monitors will therefore become more important. In the 1990s, as the gap between generating capacity and demand closes, research directed at life expansion of existing stations will inevitably assume more importance.

The long-term plan also calls for new technologies to be used to meet generation needs, and the operating groups within the Corporation will need the support of the Research Division to implement them effectively.

Combustion turbine generators and combined cycle and integrated gasification combined cycle plants are two of the technologies that have been identified. There will be others, in the next ten years.

In addition to its traditional role, the Research Division must address the growing and pressing problem of environmental damage associated with the production of electricity. Research is tackling the issue directly by developing new and better ways to deal with problems such as acid gas emissions and the disposal of ash, PCBs, and high-level nuclear waste. Research also helps increase the efficiency with which consumers use electricity. The less capacity needs to be increased, the fewer the environmental problems there are to solve. A good deal has already been achieved in these areas, but there is much more that can and will be done.

During its long history of support for the operation of the power system, the Research Division has dealt effectively with the various demands placed upon it. I am confident that it will continue to play a vital role in resolving the daunting technical and managerial challenges the Corporation will face in the 1990s.

A.R. Holt

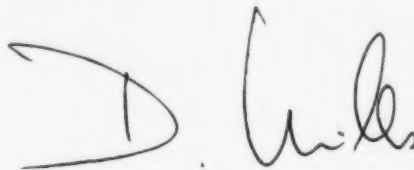
DIRECTOR'S MESSAGE

During the past year, the Research Division underwent a comprehensive review of its organization and productivity. The completion of this process has positioned the Division to meet both the technical and management challenges of the coming decade. Because of the implementation of new technologies and the ever increasing demands being made by our customers upon an aging power system, the scientific and technical support provided to the Corporation by the Division can only grow in importance.

For more than seventy-five years, Ontario Hydro has been investing in the "technological insurance" provided by the products of research and development. This investment has provided benefits in avoided costs and improved reliability that have far exceeded the costs of operating the research function. Indeed, contrary to the traditional view, R&D should be considered a profit-making enterprise rather than an additional cost of doing business. In the coming years, the need to maintain and extend the life of existing facilities and to provide support for new technologies will increase the need for the Research Division to perform its function efficiently and effectively.

In 1989, the Research Division had many opportunities to demonstrate how the Corporation's investment in research has paid off. A number of these examples are described in the theme article, which considers the role of R&D in the provision of "technological insurance" to the Corporation. Topics covered in the article range from the development of a new concrete, through the investigation of the impact of zebra mussels on system operation, to the development and implementation of a novel gas flow measuring device in a nuclear station. It is important to remember that the benefits deriving from this work result as much from the years of investment in the development of expertise as they do from the projects described. Without a continuing investment in anticipatory research, the future needs of the Corporation cannot be well served.

In the past, the staff of the Research Division have risen to the challenges provided by Ontario's power system, by new technologies, and by organizational issues, and through their endeavours, have built an enviable record of success. I would like to thank the Managers of the Research Division and their staff for contributing to this longstanding record of achievement in 1989.

A handwritten signature in dark ink, appearing to read 'D. Mills', with a stylized, cursive script.

D. Mills

SAFEGUARDING CORPORATE INVESTMENT: RESEARCH AND DEVELOPMENT AS TECHNOLOGICAL INSURANCE

Ontario Hydro is entering a critical period. If the reliability and economic price of electricity, a product that Ontarians take for granted, is to be maintained, the very best value must be extracted from every available megawatt of electric power that Ontario Hydro produces. To provide the very best value, the Corporation's generation, transmission, and distribution facilities must be operating reliably at a cost that reflects maximum benefit with minimum expenditure. It is essential that Ontario Hydro meet these challenges because, overall, the province is experiencing a five-percent increase in demand for electrical energy each year. Growth in electrical demand is tied to growth of the economy, so that the long-term trend, in spite of transient fluctuations, will be ever upward.

It is now generally recognized that the economy is becoming increasingly dependent on the successful implementation of a wide range of new technologies. It is fortuitous that Ontario Hydro has always implicitly accepted this fact and has pioneered technological innovation for more than 80 years. This pioneering spirit has led to a successful integration of an in-house Research and Development (R&D) capability with the utility's engineering and operations functions. The integration has paid off: the investment in R&D has provided benefits in avoided costs and reliability of supply that have far exceeded the cost of operating the research function. At the Research Division, effort expended on R&D is viewed as an effective means to protect the Corporation's considerable assets by the provision of "technological insurance".

Ontario Hydro's R&D capability has been further enhanced by the development of links with other organizations and by an active search for funding from other utilities (most notably through the Canadian Electrical Association and the Electric Power Research Institute). A related and useful activity is the forging of links with individual utilities and universities and participation in industrial development projects aimed at solving operating problems. One such problem, which is related to the reduction of SO₂ emissions, is occurring in large electric smelting furnaces. All these activities allow the Research Division to fulfil its mission of providing the very best technological leadership through research and development, which creates opportunities for researchers to help Ontario Hydro meet its goal of supplying reliable power safely and at the best possible price.

A high priority for Ontario Hydro is the protection of its thirty-billion-dollar investment in physical plant. Maintaining the integrity of the utility's nuclear, hydraulic, and thermal stations is important not only in terms of dollar savings, but also in terms of ensuring the optimal functioning of the whole of Ontario's power system in the future. Theoretically, if a potential problem can be identified and the right solution found before it becomes critical, the operation of a generating station can be extended far beyond its planned in-service life span.

The Civil Research Department is heavily committed to making significant life extension of physical plant a reality. In a search for repair materials that can ensure the optimal reliability of generation and transmission facilities, a considerable amount of work has been done on the identification and assessment of the long- and short-term physical characteristics of repair materials suitable for concrete structures.

Placement and handling of materials used in the construction and repair of transmission lines always presents a challenge. The perfect material would allow a field worker to mix it, place it, and walk away from it. When repairs are needed in remote locations, such as in northern Ontario, these three criteria are of inestimable importance. Ironically, winter is the best time to carry out transmission line construction and repair because frozen ground makes access for heavy machinery easier. Severe winter conditions, however, cause serious problems in the placement of concrete foundations since normal Portland cement will not develop strength under cold temperatures unless costly and time-consuming concrete curing precautions are taken. These precautions include preheating the rock surface for 24 hours and then, when the concrete is placed, covering the repair area, and keeping it heated for three days in order to properly cure the concrete. The value to Ontario Hydro of a concrete that could be placed without such measures is significant.

As a response to this need, in collaboration with a local manufacturer, a polymer-based concrete was developed. The material was revolutionary. The very-low-temperature concrete properly cures and develops its full strength at temperatures as low as -25°C without the need for heating and housing.

The material was developed over the period 1986 to 1988, with its first application beginning in late 1987. The concrete is expected to have significant and wide ranging benefits not only for Ontario Hydro, but also for the construction industry at large.



Repairs to concrete foundations of transmission towers contribute to an increase in their lifespan. Repairs have been greatly facilitated by the development of low-temperature concrete.

The low-temperature concrete obviates the need for costly provision of heat, thereby shortening dramatically cold weather concrete placing schedules. Construction flexibility is improved, and project costs are reduced, both of which serve to benefit builders and customers. Of benefit specifically to Ontario Hydro was a six-month reduction in the overall schedule required to construct a transmission line between Hanmer and Mississagi transformer stations, a distance of 200 kilometres. The material has also been used to replace deteriorating concrete footings on energized transmission lines within half a working day.

Tangible benefits to the Corporation are significant. Two million dollars were realized to date, with future savings over the next several years expected to be in the hundreds of millions. External to the Corporation, this innovative concrete has made its mark. It has been used successfully in bridge construction and maintenance and in other major construction projects in North America.

A dam failure has the potential to harm lives and towns, as well as the environment. Additionally, the cost of lost power attributable to dam failure could be considerable. The importance of a system that can give early warning of potential dam failure is obviously important. The monitoring systems being developed by the Civil Research Department will make it much easier for staff to react to, and resolve, a problem before it becomes serious. New electronic monitoring instrumentation being designed in the remote monitoring project will replace those local monitoring systems currently in use. Once completed, newly developed instrumentation will provide automatic, immediate, and continuous data that can alert off-site staff to potential problem areas. Successful implementation of these systems at hydraulic stations will provide engineers and technicians with timely information on the behaviour of dams and ensure that these facilities will continue to be available for electricity generation.

Another process that impacts significantly on ensuring the continued reliable operation of generating plants is the corrosion-induced degradation of critical components. Particularly at risk are steam generators and heat exchangers, and significant and successful work on the understanding of the corrosion process as it relates to these components has been ongoing for a long time.

Work on steam generator corrosion actually began in the mid-1970s. At that time, although Ontario Hydro's steam generators were giving outstanding performance, the rest of the world was beginning to have problems with these components. It was recognized that, although the utility's steam generators were operating well, the global situation was giving early warning of the risk of similar problems developing.

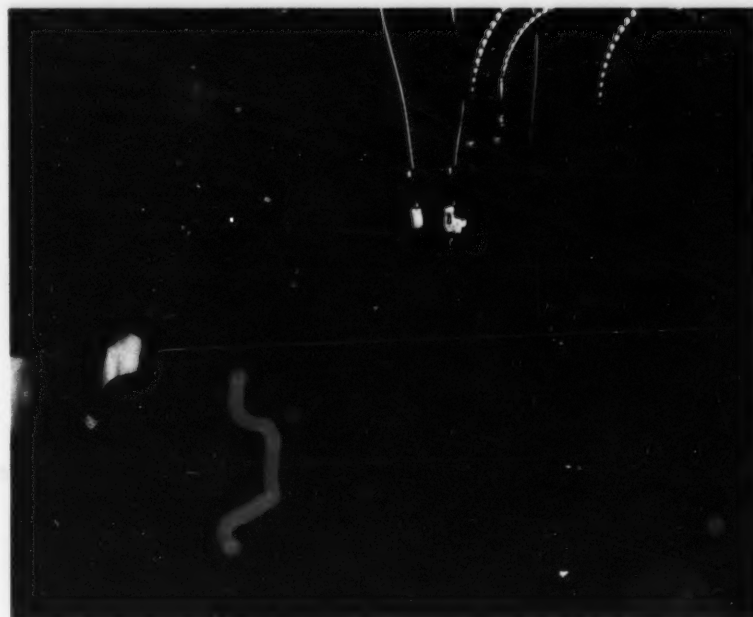
In the Canadian Deuterium Uranium (CANDU) system, steam generators represent the thinnest and largest surface area of the primary system pressure boundary. Failure of this boundary could lead to heavy water leaks and consequent shutdown as well as to



A field inspection of concrete footings is in progress. Non-destructive test equipment allows in situ inspection of the foundations.

early repair problems. In addition to leakage, fouling of steam generators or their support structures could cause unit deratings, which would incur major economic penalties. Reliable steam generator performance is therefore essential. The approach to warding off potential problems is comprehensive, and research in this field has concentrated on two main areas. First, work to optimize system chemistry by isolating and defining the consequences of unexpected changes in chemistry on system integrity was carried out to prevent reliability problems from occurring. Second, chemical methods have been developed to remove corrosion-inducing deposits, if these were to become of concern to operators.

As part of corrosion studies on steam generators, Alan McBride, chemical technician, injects chemicals into a high-pressure autoclave to remove oxygen in the solution.



More recently, the importance of biological activity in the corrosion damage of heat exchangers has been undergoing close scrutiny. Corrosion of these components has the potential of contributing not only to increased operating costs, but also to the cost of replacement energy and for materials needed to replace heat exchanger components.

The biological factor is only one aspect of what appears to be a complex multidisciplinary chemical, biological, and physical interaction, which becomes active in the corrosion process when new heat exchangers are first exposed to lakewater. At this time, the heat exchanger is readily colonized by microorganisms. Proliferation of these organisms and an accumulation of organic and inorganic materials lead to the formation of a biofilm on metal surfaces, which facilitates subsequent breakdown of the protective oxide layer. Pitting and under-deposit corrosion can occur as a result. Sulphate-reducing bacteria (SRBs) are frequently implicated as causal agents.

The recognition of the importance of microorganisms in heat exchanger corrosion failures prompted the initiation of two major research projects. The two projects, which began in 1989, share the objectives of increasing understanding of the role of biological factors in the corrosion process and in determining ways to reduce the amount of corrosion. The first project will determine whether the surface modification of heat exchanger materials increases resistance to corrosion; the second will determine the role of anaerobic microbes in the pitting of heat exchanger materials. A successful research outcome will reduce the risk of failure attributable to microbially influenced corrosion. The potential benefits are substantial reductions in capital and operating costs for heat exchanger systems at both nuclear and fossil-fired generating stations. Technology transfer could extend these benefits well beyond Ontario Hydro into the private sector, a concomitant effect being an advance in corrosion control technology. Both projects will be conducted under accelerated test conditions. Corrosion activity will be monitored by using electrochemical techniques in conjunction with subsequent surface analysis.

Irene Cord, biological researcher, counts sulphate-reducing bacteria (SRBs) in a culture. SRBs are frequently implicated as causal agents in the microbially-influenced corrosion processes.



In the laboratory, metal samples, including some surface modified materials, are exposed to accelerated corrosion conditions by immersion in cultures containing sulphate-reducing bacteria. The samples are removed for testing and surface analysis at predetermined intervals. It is expected that surface coatings will influence corrosion rates by changing the extent of biofilm adhesion, by modifying the electrochemical properties of the metal surface, and by presenting a physical barrier to aggressive chemical and bacterial species. The resulting data should provide a clear indication of the role of surface modification in reducing corrosion rates and microbial attachment.

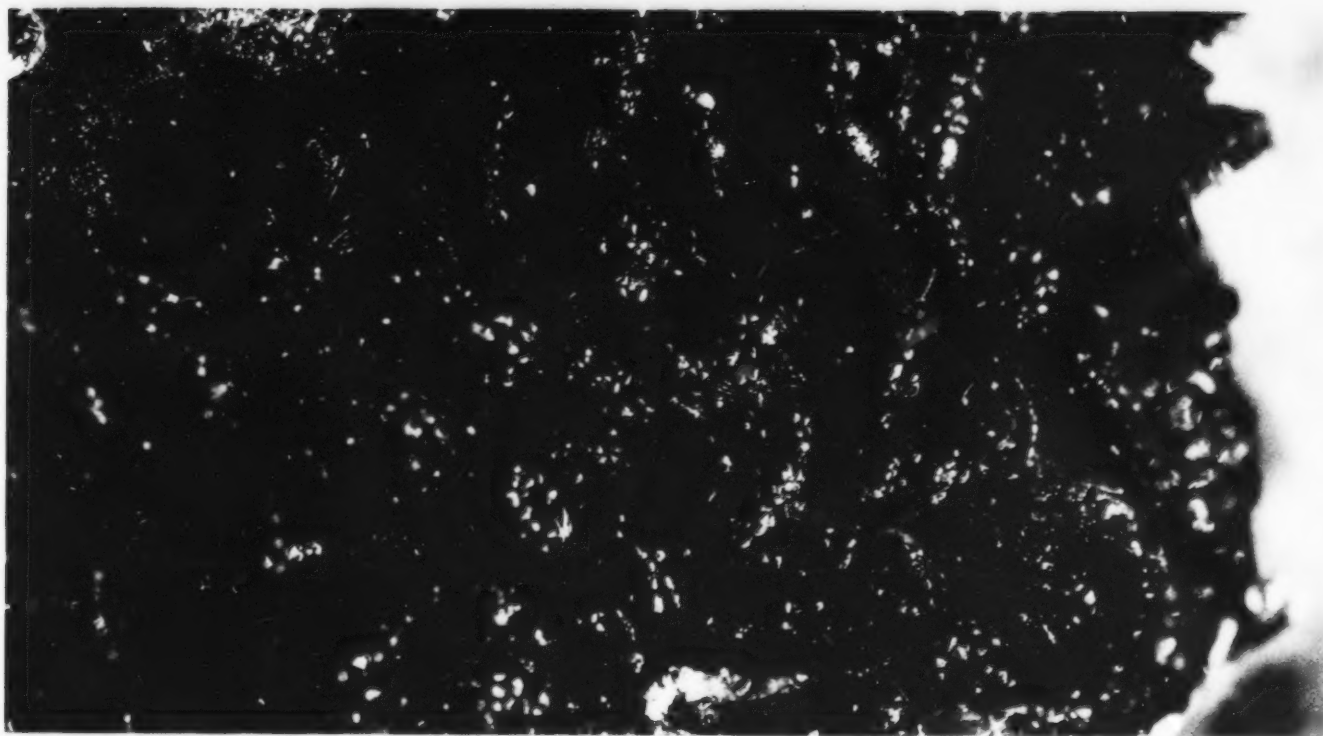
The intensive laboratory component of the surface modification project is to be complemented by a field component. In the field study, heat exchanger tubing, treated in the same way as the laboratory samples, is to be placed in a test rig that simulates conditions within a moderator heat exchanger. The resulting data will permit comparison of laboratory results with those obtained under actual operating conditions.

Multidisciplinary problems require multidisciplinary approaches. Consequently, involvement in the study team is wide ranging, involving water chemists, biologists, corrosion experts, and electron-optics specialists. The project also involves close collaboration with the Chemistry and Metallurgy Section of Central Production Services.

Ontario Hydro's operation is being threatened by an unusual problem. An exotic species of mussel has been introduced in the Great Lakes. *Dreissena polymorpha* (the zebra mussel), a common freshwater bivalve of European origin, was introduced into Lake St. Clair in 1985. The organism, undoubtedly introduced as a result of discharge of ballast water from a European ship, will, if uncontrolled, foul the water intakes of Ontario Hydro's generating plants situated on the Great Lakes. The problem is one with which the European power industry has been wrestling for many decades.



Biologists inspect rocks at Mohawk Point on Lake Erie. As suspected, the zebra mussels have spread along the northern shore of Lake Erie within one growing season.



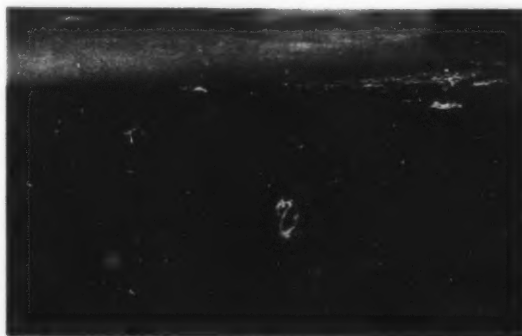
Since its introduction into Lake St. Clair, the zebra mussel has spread rapidly to the Detroit River and the Western and Central Basins of Lake Erie, as far as Port Maitland. The species has already reached Lake Ontario, and its ultimate spread into the rest of the Great Lakes and inland waterways appears inevitable. As a response to this escalating and potentially serious situation, the Biological Research Section of the Chemical Research Department has been participating in a concerted multidisciplinary effort to ensure that remedial strategies were in place prior to the organism's arrival at Ontario Hydro's generating stations.

Without proper control, the mussel will undoubtedly colonize parts of Ontario Hydro's water intake structures, which will result in detrimental effects that include severe restriction of cooling water flow in generating plants. Additionally, their growth or the impingement of shells on condenser and heat exchanger tubing may diminish plant performance through blockage or degradation of heat transfer. A concomitant problem may be the corrosion-inducing anaerobic bacterial activity that may occur underneath excrescences of the zebra mussel.

Once established, zebra mussels spread quickly. By May 1989, the Chickenolee Reef, an important spawning ground for whitefish and walleye, was 90 percent covered by a single layer of mussels and, by October, was totally buried three layers deep. The loss of this reef and others like it could herald the loss of walleye and whitefish as commercially valuable species. More ominous for Ontario Hydro's operation is that, by the spring of 1989, mussels had already begun to show up in the intake pipes of eight municipal water treatment plants on Lake Erie, the Detroit River, and Lake St. Clair. By October, the intake capacity of the pipes was down twenty five percent. The pipes, some of them, six kilometres long, will have to be replaced at a cost of \$1 million per kilometre.

As no universally acceptable method of controlling the mussel exists, and the need for mitigating action is immediate, information from research studies is urgently needed to develop a control strategy. Currently, a successful dispersal monitoring program is in place that allows early detection and subsequent tracking of the mussels' progression. By September 1989, the organisms, at the settlement stage of their development, were identified over the intake valves of Ontario Hydro's Nanticoke power station, which is situated at the east end of Lake Erie. Monitoring blocks submerged in the forebays of the station indicated that infestation was at a density of 100,000 mussels per square metre. Ontario Hydro's Environmental Protection Department had anticipated their arrival and had installed fine mesh screens across internal pipes. At this settlement stage, however, the mussels are minute, approximately 0.2 mm in length (no larger than the tip of a pen), so that they can easily pass through most fine strainers. Further inspection confirmed that colonization in service water piping and in fire protection systems had taken place. Intermittent control treatments began in October.

Zebra mussels settle one on top of the other. The resulting thick layer can create major clogging in water systems infested by the species.



Divers inspect zebra mussel-infested rocks offshore. Determination of distribution at various depths may help in the development of strategies to preclude infestation of stations.

To supplement the use of monitoring blocks, plexiglass sidestream samplers, with growth chambers, have been designed for use in each station. These transparent boxes contain removable plates that are fabricated from materials used in the construction of generating plant and from materials known to be favourable for mussel attachment. If mussels are present in any system, they can be readily detected upon examination of the plates.

To develop an effective control strategy for the zebra mussel, an extensive knowledge of its ecology and physiology is required. A breeding colony is being established in the laboratory for use in long-term studies designed to provide information on the organism's response to currents, temperature, pressure, turbulence, and thermal shock. Simultaneous field studies will collect data on depth distribution, reproductive habits, growth, seasonality, and substrate preference. Although it would appear from initial studies that at least several aspects of the biology of *Dreissena* in Lake St. Clair resembles European populations, the findings will need verification. This research is being conducted in conjunction with the University of Guelph.

Judy Kwik, biologist, determines the density of mussels on rocks at Mohawk Point. The rate of growth of mussels can be determined by changes in their size and structure.

The current practice of using various chemicals to control mussel populations may not be approved by the Ministry of the Environment for continuous use. And even if a few chemicals are approved, they will have to be thoroughly evaluated with respect to their potential effect on other organisms. Alternative controls are being investigated, and these include ozonation, filtration, anti-fouling coatings, and use of electric fields. As each type of control has limited usefulness, it is likely that total control will involve a combination of various technologies.

The work on the zebra mussel clearly demonstrates how a research capability and active research in a variety of areas provide the Corporation with a "technological insurance policy". This policy will ensure that few surprises occur with attendant major failures of the bulk electricity system and that, when crisis situations arise, effective support is available to quickly provide ways to correct the situation. The research and development work can be viewed as an activity designed to protect the Corporation's assets. In this light, research and development can be seen as a major underpinning of the province's future economic growth.



Instrumentation and monitoring systems have been installed in hydraulic stations to facilitate assessment of their condition, which, in turn, determines maintenance needs in a timely manner.



Ontario Hydro's nuclear facilities are not exempt from scrutiny. Like other types of power plants, nuclear stations are susceptible to aging. Even the aging of Darlington, not yet fully in service, must be taken seriously because, when this station is on line, nuclear power will account for fully 60 percent of the utility's total energy production.

When compared to their original design life of 40 years, Ontario Hydro's nuclear power plants are relatively young, the oldest commercial plant being approximately 17 years old. By the year 2000, however, several units will be approaching "old age". Thus the question of maintaining safety and reliability of aging nuclear plant is becoming increasingly important. Yet, age-related degradation of plant components is a complex phenomenon not yet fully explored.

It is fortunate then that expertise developed at the Research Division has found useful application in a most important multidisciplinary Nuclear Plant Life Assurance (NPLA) program. The overall program is designed to address uncertainties about age-related degradation of plant components so that potential problems can be identified and resolved before any loss of safety or reliability of supply occurs. The program draws on expertise from six of the Research Division's departments, the overall program being directed by an inter-divisional steering committee with representatives from Design and Development, Nuclear Generation, and Central Production Services Divisions.



Mark Tinkler and Murray Mathers of the Research Division and IREQ's Jean-Luc Fihey look on as Hydrobot, a portable robot developed jointly by Ontario Hydro and IREQ, repairs cavitation damage on a turbine runner.

Research Division efforts directed toward ensuring the optimal performance of Ontario Hydro's nuclear plant are covered by two elements of the NPLA program. One element is committed to assure the life of nuclear plants during their normal service life of 40 years; the other element concerns life extension, which provides the option of extending the life of nuclear plant beyond normal service life.

The first step in the NPLA methodology is to divide plant components – a nuclear plant has thousands – into two categories, critical and noncritical. Noncritical components are those that can be easily and economically replaced and critical ones are those that are neither easily nor economically replaced, the failure of which would impact negatively on the safety, reliability, or life expectancy of a plant. Based on specific selection criteria, the list of critical components is prepared and includes items such as fuel channels; steam generator; the calandria vessel, its supports and cooling system; primary and secondary heat transport system; vacuum building; and cables.

The second phase of the program serves to identify what needs to be done. For each critical component, necessary initiatives are formulated to achieve an understanding of aging mechanisms, an early method of detection and prediction of age-related degradation, and a means of restoration of lost performance.

The decommissioning of the Nuclear Power Demonstration (NPD) nuclear station after 25 years of operation provided the NPLA program with an excellent opportunity to examine naturally aged plant components and materials. Since the plant components at NPD had been exposed to their operating environment longer than components in any other CANDU plant, their examination will be invaluable in the identification of aging mechanisms not yet encountered in younger stations.

During 1989, several research and development programs were identified as being necessary to support the NPLA program. The thrust of these programs was to assess the effect of service-related degradation mechanisms on materials used in the manufacture of critical components. The goal is to devise a standardized evaluation procedure to monitor and predict the remaining life of nuclear plant components.

For example, assessment of fatigue damage and evaluation of fatigue crack growth and metal weld degradation are expected to be aided by the development of a data base of the properties of materials. Similarly, the extensive use of cables has given rise to another area in which new research and development initiatives have been identified. As a response to the critical nature and significant cost of installing cables, a program has been proposed to develop techniques to monitor and assess cable degradation and to predict remaining life. One technique under consideration will be to develop cable jacket materials that will indicate through an obvious colour change whether the materials have been exposed to damaging conditions.

The reliability of Ontario Hydro's plants is also enhanced by the development of sophisticated diagnostics, which allow determination of the actual condition of electrical equipment such as generators,

motors, transformers, and switchgear. Appropriate diagnostics can warn operators of incipient problems well before a forced outage occurs, thereby allowing timely corrective action to be taken to minimize the impact on the power system. Some types of generator problems can be detected years in advance of actual failure, which permits maintenance measures to be planned in an orderly fashion, often at a fraction of the cost of a repair made on a reactive rather than on a planned basis.

Specific diagnostic instrumentation that has been developed to date at the Research Division includes a Partial Discharge Analyzer that can evaluate the condition of stator insulation in hydraulic generators. A similar technology is being evaluated for detection of comparable faults in turbine generators, the monitoring of which has been much enhanced by a novel application of laser-based phosphor thermometry technology. A nitrogen laser puts out pulses of ultraviolet energy, which are then delivered by an optical fibre to excite a phosphor-resin mixture painted on the surface of the rotor. The resulting visible fluorescence is then picked up by a second optical fibre and transmitted to a detection system external to the generator. The light passes through a filter to isolate a particular emission line, which is then detected by a photomultiplier tube.

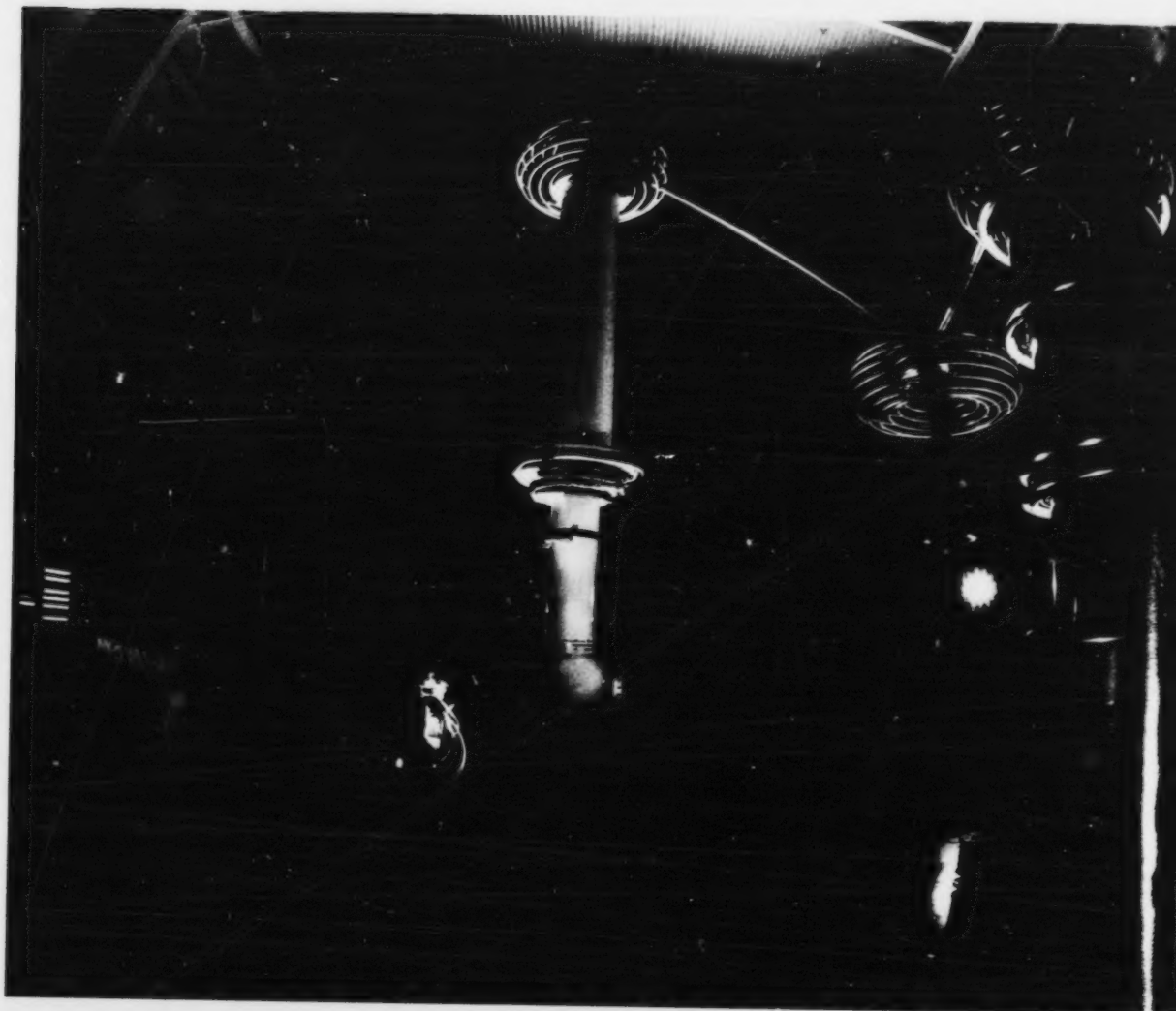
Silvano Rizzetto of Electrical Research monitors an ultra-sensitive detection system that is used to test epoxy insulators used in gas-insulated switchgear.



To make the most effective use of new and extensive conventional sensor data, a Generator Expert Monitoring System (GEMS) is being developed that incorporates advanced knowledge of machine operation to correlate the data and make recommendations concerning the condition of the turbine generator.

Data collection and analysis are performed by a microcontroller-based system that first synchronizes the pulsing of the laser and the rotation of the rotor, so that the laser acts like a stroboscope to illuminate one spot on the rotor, and that subsequently determines temperature by evaluating the decay time of the phosphor emission by comparing it to a calibration table. This novel diagnostic tool can give generator operators information to which they are currently not privy: namely data on temperature at specific locations along the length of the rotor. This will give advance warning of localized hotspots attributable to overheating of rotor insulation. This information can be used to prevent untimely equipment failure.

To assure long-term reliability, an ultra-sensitive detection system has been developed to test epoxy insulators in gas-insulated switchgear.



Laser technology is an important component of another piece of important work ongoing in the Research Division: the work allows measurement of the flow of annulus gas within the CANDU reactor. First, an explanation of the annulus gas system.

In the calandria of the CANDU reactor, pressure tubes containing nuclear fuel and hot pressurized water are surrounded by an annular space through which dry, chemically inert gas is flowing. Taking advantage of the presence of this dry gas provides the basis of a safety feature unique to the CANDU system. Continuous monitoring of the gas for moisture is important diagnostically because the presence of moisture in the gas could indicate a leak in a pressure tube, the detection of which permits automatic shut-down of a reactor.

In order to be able to monitor for moisture, it is necessary that gas flow be maintained in the annular space around each individual pressure tube. The ability to verify that flow is present, and at what rate gas is flowing, can assure the very highest level of leak detection.

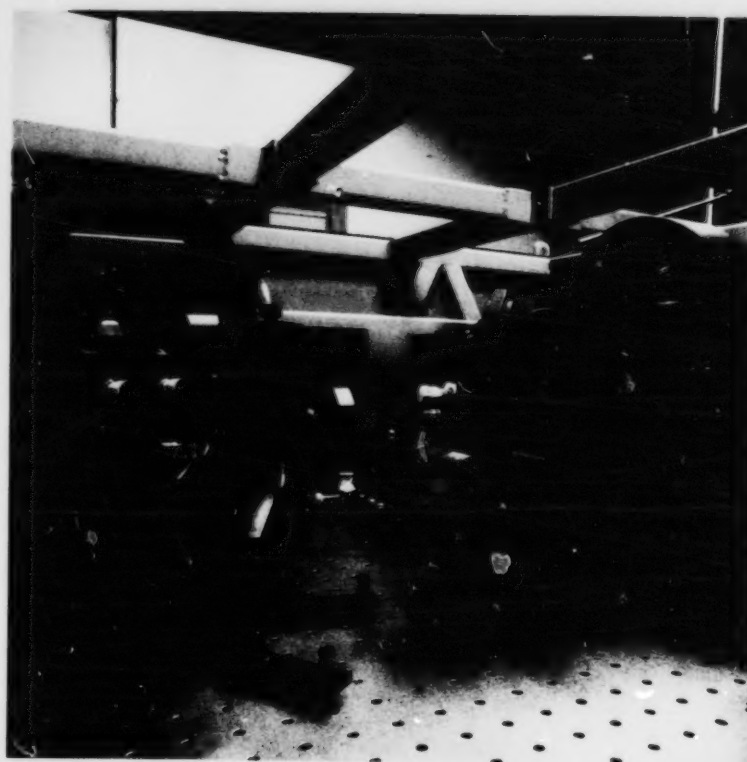
In addition to the safety concerns that could exist if a means of monitoring the flow of annulus gas were not available, there is also a hypothesis that, if pressure tubes are not subject to adequate gas flow in the annular space, they may demonstrate a higher rate of pickup of hydrogen than would otherwise be the case. Since hydrogen pickup is thought to be the factor that causes pressure tubes to become brittle, which results in expensive retubing operations, the validity of the theory is important.

During the past year, Pickering Unit 3 was scheduled to be shut down for retubing operations. The situation provided researchers with a unique opportunity to prove or disprove the theory that relates to the relationship between hydrogen pickup and pressure tube embrittlement. This is because Pickering 3 could have all its tubes analyzed for hydrogen content after their removal. However, to make sense of this data, it was imperative that the annulus gas flow rate in each tube be determined before the reactor was dismantled and retubing began. If the annulus gas flow rate at Pickering 3 had not been measured before the dismantling operation began, the information leading to an understanding of the correlation between annulus gas flow and hydrogen pickup would have been lost forever.

It was fortunate that a method of measuring gas flow in the annulus existed, at least conceptually. The original concept involved heating a "pigtail" with an electric heating element. Pigtails, so-called because their purpose of connecting the fuel channel gas annuli together sometimes required that they be looped around the channel to allow for expansion, were then photographed with a heat sensitive camera. In the laboratory, it was shown that, if gas were flowing, the hot spots appeared asymmetric.

In practice, however, there were many obstacles to overcome. The major problem was one of access. The annulus gas flow has to be measured within the CANDU reactor, a difficulty compounded by the fact that the reactor face is extremely congested with a forest of equipment. Additionally, pigtails are sometimes two metres from the closest point that can readily be accessed with measuring equipment. The objective was to build a non-invasive tool capable of measuring gas flow in all the pigtails of Pickering 3 reactor channels prior to the retubing operation, which was scheduled at the outset of the project to begin in mid-October 1989.

Early in January, a team was assembled. The work, funded by Central Production Services Division, required a wide range of internal expertise. This expertise was drawn from the Research Division, Nuclear Systems Department, Supply Division, and Design and Development Division. The basic idea had been undergoing some refinement. To overcome the access problem, a highly focused carbon dioxide laser was proposed to heat up designated pigtails. When the laser beam was removed from the designated spot, the infrared camera could be used to detect the presence or absence of flow. The concept was further refined by the addition of image processing to measure the extent to which the hot spot had been affected by flow, thereby allowing a quantitative measure of flow.



Fifteen years of laser and optics experience were applied to refine the concept further. A computer was used to continuously capture and analyze the infrared image of the cooling pigtail. Another important development was the addition of a helium-neon laser collinear with the infrared laser. This development allowed the production of visible red light, which allowed the infrared laser to be more accurately aimed at the pigtails by operators. The final addition of a steerable mirror for fine positioning of the laser obviated the design problems associated with attempting to position the whole assembly with the required accuracy.

In the laboratory, the refined design allowed flow rates inside tubes to be easily measured down to flows as small as 100 ml per minute. In the station, however, a major problem arose. Whereas in the laboratory good measurements of flow rate could be obtained with analysis of data taken over a 175 mm segment of tube, in the field the much shorter 25 or 50 mm of pigtail available for observation made getting good results very difficult. Over a period of several months, many different approaches to the problem were taken, but with little success. Diligence and hard work, however, paid off in the end when, after trying over 50 different computer algorithms, one was found that allowed reliable measurements to be made on small data sets.

The heart of the annulus gas thermography tool consists of sophisticated modern optics and lasers, such as the computer-steerable mirror, infrared camera, and CO₂ laser shown here.



The laser thermography tool control allows operation of the tool from outside the reactor vault.

Equipment was built, tested, and commissioned before the imposed deadline. It weighed approximately 1 500 kg, was to be approximately 1.5 x 3 x 0.5 metres in size, the whole assembly to be mounted on a lift. The equipment was operated remotely, some two metres away from the reactor face. A mockup of the reactor was also required to train personnel how to use the equipment. The mockup was built in just six weeks in the Central Maintenance shops, much time being saved because a design already existed. Atomic Energy of Canada Limited (AECL) made drawings available that had been developed for the Pickering retubing project.

The project was successful, and though the results are still being analyzed, they are expected to be far reaching. The project as a whole attests to what can be accomplished with a good team and the necessary expertise.

In what is expected to be an exciting and challenging future, Ontario Hydro will continue to meet its traditional goals of supplying its customers with reliable power at the best possible price. To help ensure that these goals are met, the Corporation has been investing in R&D for over 75 years. This investment has paid off during these years. The expertise made available by the Research Division has benefited both the Corporation and its customers, and the Research Division will continue to expend its effort to provide the Corporation with what amounts to a technological insurance policy. The examples of current work ongoing in the Research Division that have been described in this article give some insight in the scope of its activities. The Division's future effort, through to the next century, will be to capitalize on innovation through R&D as a means of building on Ontario Hydro's strengths and of safeguarding a sizeable Corporate investment in physical plant.

Through
excellence,
innovation, and
internationally
acclaimed research,
we will be
leaders in the
introduction
of new
technologies
to
Ontario Hydro
and the
electrical industry.

CHEMICAL RESEARCH: MANAGER'S OVERVIEW

The Chemical Research Department provides the Corporation with a technical resource that includes process and materials chemistry, chemical analysis, biology, and environmental science. A staff of approximately 140 chemists, chemical engineers, biologists, and highly skilled technicians conducts research, performs technical investigations, promotes energy efficiencies in the chemical industry, and offers problem solving services related to the chemical, biological, and environmental aspects of electric power generation. Specialized experimental facilities and state-of-the-art instrumentation for measuring and analyzing experimental parameters are used in this work. Comprehensive chemical analytical services, which support the research programs of the Division as well as the Corporation, are also provided.

"Chemical Research's staff, sophisticated equipment, and directed research programs are essential ingredients of the Corporation's technological assurance package."

Dave Dodd, Manager

Technical staff, ongoing research programs, and sophisticated departmental facilities and equipment provide the necessary ingredients for the provision of innovative ways for Ontario Hydro to identify and prevent problems and to respond quickly and effectively to them, if and when they arise.

Almost one-third of the Department's resources support the Corporation's nuclear commitment. Work ranges from research on maintaining steam generator tube integrity to work on developing nuclear waste management options. A containment leak test using a tracer gas technique and an ultrasonographic method was developed and used successfully at Bruce NGS "A". This capability was used to demonstrate to the Atomic Energy Control Board (AECB) the performance of the vault cooler fans and hydrogen ignition systems at Darlington NGS.

Prevention of worker exposure to radiation and hazardous substances is addressed by research programs that range from development of respiratory equipment for workers, to component and full-system decontamination processes. An alternative to the discontinued Stephenson respirator for protecting against tritiated water vapour was developed in collaboration with manufacturers, and as part of this project, alternative sorbents and prototype respirators were evaluated. Studies of the tritium behaviour with non-metallic materials are conducted to select protective barriers for use as gloves and suits and to develop decontamination methods.

As long as the process chemistry is properly controlled, the CANDU Decontamination (CANDECON) process for decontamination of heat transport systems is successful. The Department's expert analytical capability and experience in decontamination process development played a major role in providing monitoring for the successful decontaminations carried out last summer in Pickering Unit 3. A collaborative effort with Central Production Services Department and AECL-Chalk River to develop and qualify a dilute oxidizing pre-treatment for end-fitting decontamination resulted in the first full-system application of the process. Work with the University of Guelph will allow greater understanding of the mechanisms of oxide dissolution and corrosion during decontaminations. A successful outcome will help ensure that appropriate and reliable decontamination technology is available to the Corporation.

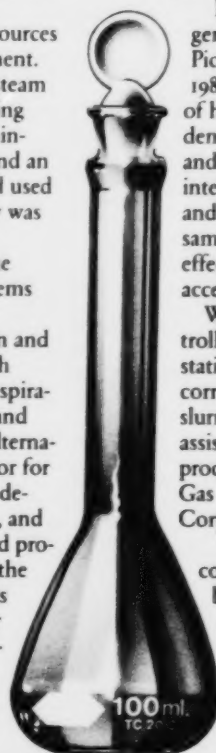
In the nuclear waste area, the Department is involved in an extensive program to monitor the performance of a concrete integrated container designed to transport and store spent fuel. A two-year demonstration is underway at Pickering NGS. After a suitable decay period, low- and intermediate-level radioactive wastes may be treated more economically as non-active wastes. The Department is monitoring the effect of long-term storage on waste packages, packaging materials, and engineered storage structures in the laboratory and in the field. Research has been performed to identify potential chemical hazards in radioactive wastes and to develop immobilization methods.

Chemical research supports the Corporate goal of developing and managing its activities and facilities so as to protect the environment. Areas of work range from monitoring the effects of Ontario Hydro's operations on ecosystems to developing new means of emission control.

Pre- and post-operational studies of the effects of generating facilities on the aquatic environment at Pickering and Atikokan are almost complete. In 1989, a technique to verify spawning and the date of hatching of round whitefish was successfully demonstrated. Techniques such as radiotelemetry and enhanced sonar systems, coupled with artificial intelligence techniques, are being developed to track and identify fish. Such non-consumptive and remote sampling systems will make future surveys more effective, less costly, and environmentally more acceptable.

Work in support of Ontario Hydro's plans for controlling acid-gas emissions from thermal generating stations includes studies of reagent regeneration, corrosion, and gypsum production in the limestone slurry or dual alkali processes. The Department has assisted Design and Development Division in the process selection and tendering phase of the Acid Gas Control Program and in the acquisition of FMC Corporation's limestone dual alkali technology.

The Combustion Research Facility, at which the combustion characteristics of different coals can be evaluated, has proved invaluable as a site for the development of a sorbent injection system for simultaneous removal of SO_2 and NO_x .





Biologists Scott McKinley and Henry Kowalyk of Chemical Research are tagging a lake sturgeon in the Mattagami River as part of a study to determine the effects of the operation of hydro-electric stations on the existence of the species.

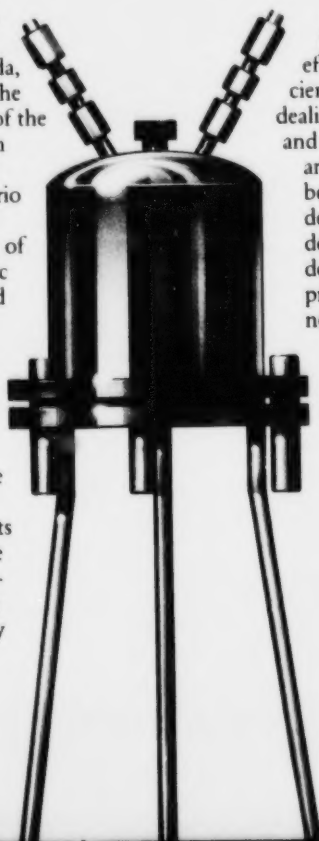
This facility was recently upgraded with a new coal-grinding and pneumatic feed system and a new sophisticated electrostatic precipitator able to collect dusts from low-sulphur fuels or in-furnace additives. The precipitator will enable researchers to help Ontario Hydro fulfil its environmental responsibilities in a more efficient and cost-effective manner.

The Department continues its search for solutions to the problem of handling PCB-contaminated wastes. The work includes the development of decontamination procedures for PCB-contaminated transformers, evaluation of PCB-replacement insulating fluids, and investigation of chemical PCB-destruction methods. During 1989, staff represented Ontario Hydro in a consortium that organized the first Canadian demonstration of a mobile PCB incinerator at Swan Hills, Alberta. This consortium included Environment Canada, Hydro Québec, the Québec Ministry of the Environment, and the Ontario Ministry of the Environment. A successful demonstration and subsequent approval for commercial operation in Ontario would permit Ontario Hydro to destroy its PCB-contaminated wastes. The quantification and resolution of problems associated with leaching of toxic preservatives from the thousands of wood poles used and stored by Ontario Hydro is another example of an environmentally related study.

Whereas the foregoing relates to the environmental impact arising from the generation, transmission, and distribution of power, concerns about the natural environment's effect on these same systems is also of concern. Pollutants in the atmosphere are contributing to the corrosion of Ontario Hydro's older transmission lines, and a major refurbishment program is planned. Studies are underway

to identify the pollutants and the meteorological conditions affecting these lines. Historical and environmental data obtained in the field will be used to map the corrosivity of the atmosphere and to estimate the remaining life of transmission lines. Other work to assure the reliability of the transmission and distribution system includes a study of the role of freezing rain and fog in the occurrence of flashovers on the 500-kV transmission system. The search for more effective methods of controlling tree growth on transmission and distribution rights-of-way continues, with the objective of reducing herbicide use.

The Department's work program also supports the Corporation in numerous other ways. Assessment of the performance of organic materials used in electrical equipment and throughout the generation system; an effort to develop and introduce more efficient electrochemical processes; and work dealing with understanding climate change and the effects of electric and magnetic fields are some of these. In addition to the direct benefits derived from new technologies developed in the programs that have been described, the skills and capabilities developed at the forefront of technology provide a critical component of the technological assurance required by the Corporation. The Chemical Research Department is committed to help the Corporation meet Ontario's need for electrical service in a safe, reliable, and environmentally responsible manner.



CIVIL RESEARCH: MANAGER'S OVERVIEW

The Civil Research Department of Ontario Hydro's Research Division has been a leader in civil engineering technology for over seven decades. Departmental expertise, which includes key areas such as concrete technology and quality control, provides vital support in the construction of new facilities. Specialized geotechnical engineering support to the Division and to the Corporation as a whole is also provided.

In the Department's role of serving the research and development needs of the Corporation, projects have ranged in time and scope from the construction of Ontario Hydro's early hydraulic stations to the current construction of a world class power project, the Darlington Nuclear Generating Station.

The expertise of the Department is essential to the Corporation's Dam Safety Program. Working as a multidisciplinary team, the various sections of the Department provide services to evaluate the integrity and to monitor and assess the performance of the Corporation's hydraulic structures.

To satisfy regulatory requirements, in-service inspection of concrete components in Ontario Hydro's nuclear structures is ongoing. In support of this program, laboratory studies are being conducted. One program is an investigation that will allow better understanding of the mechanisms of loss of integrity of concrete due to leaching of its solutes when exposed to flowing deionized water. Understanding of these mechanisms is applicable to studies of containment concrete used for irradiated fuel storage bays. The durability of concrete in freezing and thawing environments is being investigated when the concrete is simultaneously under the influence of a thermal gradient and when one boundary of the concrete surface is covered with an impermeable membrane or a repair material.

The quality of concrete aggregates and their sources is reviewed periodically for suitability for use in new construction or in the rehabilitation of existing structures. Such a review includes detailed laboratory testing of aggregates to identify potential problems with respect to alkali-aggregate reactivity or to various aspects of concrete durability. A specific application of these procedures is the development of the high-density concrete used in the construction of containers designed for dry storage of nuclear waste. The applications of these procedures are wideranging; they help assure both the minimum density of concrete needed for radiation shielding and the moderately high strength needed to ensure structural integrity.

Additionally, the Concrete Control Section provides on-site inspection and testing of concrete and concrete materials for major construction projects such as the Darlington Nuclear Generating Station. Inspection and testing are also provided for rehabilitation and reconstruction of smaller hydraulic, thermal, and transmission projects.

The Civil Research Department participates in the development of national and international standards on concrete and related areas. This activity keeps the Departmental staff abreast of advances in the field. Such participation has been recognized through citations and awards received by some staff of the Concrete Technology Section.

"Research and development in civil engineering ensure the structural integrity and the continued safe and reliable performance of Ontario Hydro's generation and transmission facilities."

Tom Kline, Manager

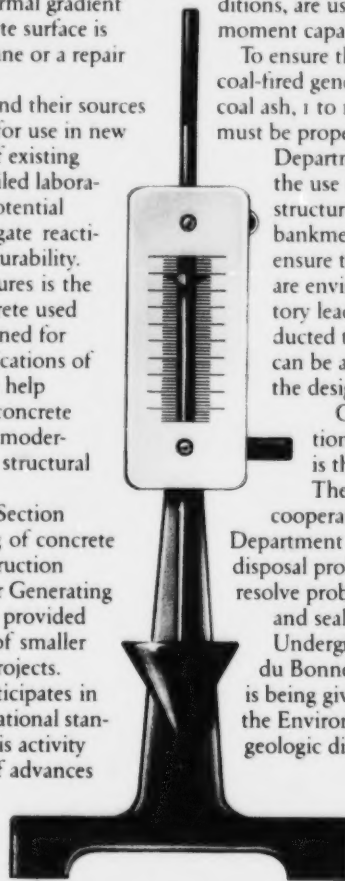
The Soil Sciences Section performs field and laboratory measurements of soil properties, which include shear strength, consolidation, dynamic behaviour, and hydraulic parameters. Experimental research work dates back to the 1950s and has produced a centre of expertise on the thermal properties of soil materials. Thermal properties are essential when determining the best backfills to use when placing underground power cables.

Transmission tower foundations must resist a wide range of compression, uplift, and lateral loads. To provide reliable, cost-effective support for the design and construction of these structures, the Soil Sciences Section carries out full-scale tests on a wide range of foundation types, including steel grillages, drilled piers, piles, grouted rock anchors, helix anchors, and grouted soil anchors. State-of-the-art design methods, derived from instrumented full-scale tests in various soil conditions, are used for determining the uplift, lateral, and moment capacities of foundations.

To ensure the smooth operation of Ontario Hydro's coal-fired generating stations, the large quantity of coal ash, 1 to 1.2 million tonnes produced annually, must be properly managed. For many years now, the Department has carried out studies to support the use of large volumes of fly ash in concrete structures, in the construction of highway embankments, and in land reclamation projects. To ensure that the utilization and disposal of fly ash are environmentally acceptable, field and laboratory leaching and geochemical tests are conducted to study leaching properties. The results can be applied when formulating guidelines for the design of disposal or storage sites.

One of the requirements for the operation of Ontario's nuclear generating stations is that nuclear waste be disposed of safely.

The Civil Research Department works in cooperation with the Nuclear Engineering Department and AECL to develop solutions to waste disposal problems. Major projects are underway to resolve problems related to excavation disturbances and sealing of underground repositories in the Underground Research Laboratory (URL) at Lac du Bonnet, Manitoba. Essential technical support is being given to AECL in the preparation phase of the Environmental Impact Statement on deep geologic disposal of nuclear waste.





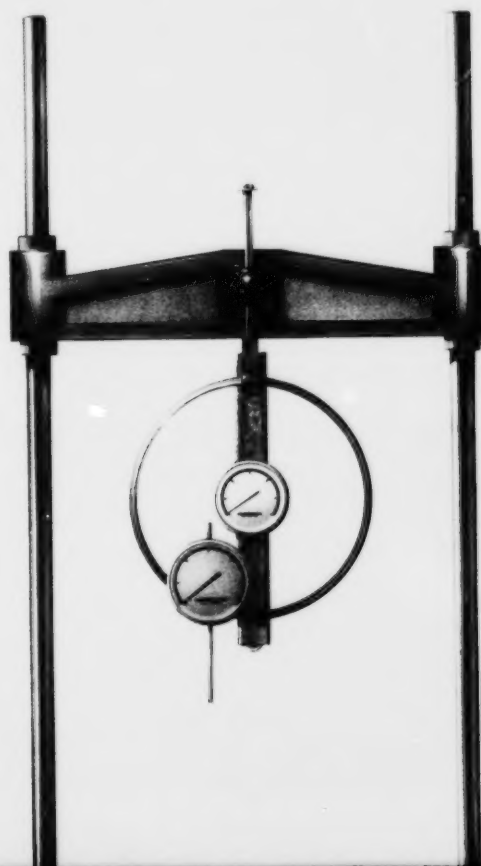
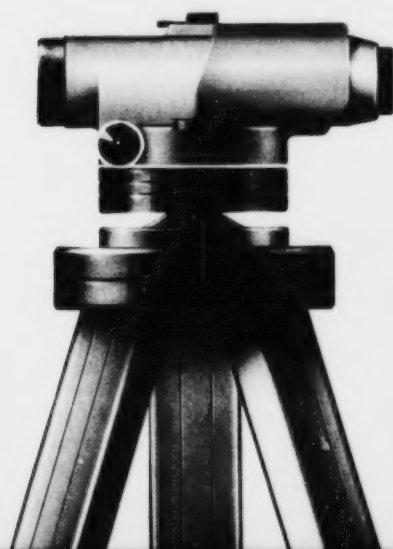
Jim Sato and Ken Hare are monitoring moisture migration through concrete structures. The project, selected to receive Director's fund support, will determine the durability of concrete and repair systems.

Clay-based buffer and backfill materials to be used in the URL project are being assessed in the Soil Sciences Section for their thermal hydraulic properties and their long-term performance. A one-eighth scale concrete model of a proposed repository design was used in the study of the near-field thermal regime. This work was done as a forerunner to the proposed full-scale URL experiment.

The Rock Sciences Section determines the mechanical properties of rock masses, which are essential for the design, construction, and evaluation of underground structures and foundations, as well as for the safety assessment of hydroelectric dams. In situ testing for the determination of rock modulus, stress, strain, fluid pressure, and convergence or deformation in rock is being routinely carried out. In situ measurements are usually preferable to laboratory measurements because they account for large-scale features of the rock mass. A number of in situ techniques have been developed. Automation of geotechnical instruments and telemetering of data from remote dams are important components of dam safety.

Hydrogeology and environmental geochemistry work focuses on field and laboratory investigations of leakage pathways from, and into, underground structures, evaluation of the isolation efficiency of engineered barriers, and the assessment of contaminant migration. Radionuclide sorption and diffusion properties of geomaterials and concrete are being determined in a radioactive materials laboratory.

These essential services of the Civil Research Department provide state-of-the-art technological assurance in support of the Corporation's mandate.



DIVISIONAL PROJECTS: MANAGER'S OVERVIEW

The Divisional Projects Department provides an interface between divisional staff and various groups within the Corporation as well as with groups external to the Corporation. The Department's major products are new technology initiatives, research management studies, and research business support.

For many years, the Research Division's mandate has been to support Energy Management Branch in its efforts to help industry use electricity wisely and to assist customers to find and implement competitive industrial processes. The Divisional Projects Department serves this dual purpose by developing new technology initiatives.

The Process Metallurgy Project continues to expand its commitment to better energy management, and a number of research programs are currently addressing issues of load reduction and potential load shifting. In addition, study efforts are assessing the impact of alternate metal refining processes with the objective of reducing CO₂ levels. The industrial effectiveness issue is being addressed through projects such as one being done in collaboration with Metallurgical Research Department and Falconbridge Limited. The project is aimed at solving operating problems that occur in large electric smelting furnaces as a result of attempts to reduce SO₂ emissions.

The Department is committed to increasing awareness in industry of the potential of laser-based processes now under development in the Research Division. Laser-based developments are quickly becoming accepted and used to advantage in the US, Europe, and particularly in the Pacific Rim countries, the greatest source of competition for Canada. The vehicle for disseminating this information is the Canadian Industrial Laser Association (CILA). CILA came about as a result of the efforts of the Divisional Projects Department. The Association has already had a number of meetings, and a managing executive has been set up. The organization boasts a strong industrial base and a strong sense of commitment.

The Research Division seeks to improve its effectiveness and efficiency by collaborating with external organizations. As part of this collaborative effort, Departmental staff, particularly those involved in new technology area, exert a strong influence on Canadian universities and industrial R&D. Influences are brought to bear through the acceptance of adjunct professorships at local universities by Research Division staff; memberships on industrial advisory councils, such as the Canadian University - Industry Council for Advanced Ceramics (CUICAC); the Ontario Centre

for Materials Research (OCMR); and the Centre of Excellence in Laser and Lightwave Research. Additionally, Departmental staff sit on Natural Sciences and Engineering Research Council (NSERC) funding committees and influence university curricula through council memberships.

This year, the Divisional Projects Department coordinated the production of the Division's business plan, and additionally, it played a lead role in the Division's annual strategy setting session. The business plan, which communicates the Division's future plans to senior management, provides direction for staff responsible for detailed work planning that spans a period of ten years.

The Division's business plan for 1989-1998 stressed the importance of providing "technological insurance" to protect the Corporation's thirty billion dollar investment in sophisticated physical plant. The plan made clear that research, specifically anticipatory research, is a necessary activity for the maintenance of this asset base. As a response, to provide the funding and the type of environment required for innovative research, a Director's Fund was established. Divisional Projects Department assumed the task of developing and administering this program. In 1989, six projects were selected from over thirty proposed by Research Division staff.

Part of the Department's responsibility lies in identifying opportunities to improve research management. Currently, research management studies are looking at the impact of computers on the way work is conducted.

"The Division's capabilities are enhanced through anticipatory research, new technology, external business relations, and research management studies"

Mick James Weiss, Manager





Technicians are tapping hot metal from a pilot electric furnace at Lakeview TGS. The furnace, built at Research Division, will be used to optimize the performance of Ontario's smelters and melters and to investigate new processes and products.

The identification and reporting of "Notable Accomplishments" also falls into this area. Notable accomplishments are R&D projects of significant benefit to the Corporation, the customers of Ontario Hydro, or some identifiable third party. Such reports are produced every five years and clearly demonstrate that the benefits provided by the Division significantly exceed the total costs for a specific five-year period.

Technology forecasting is important for research management. General long-range planning forecasts are provided biennially for the Research Program Advisory Committee. Forecasts are conducted to explore the probable development of specific technologies and their potential impact on Ontario Hydro. Assessments of the impacts of advanced industrial materials and high-temperature superconductors are two examples of recent forecasts.

The Divisional Projects Department also carries out the very important Directorate support function. This year, the Department arranged and coordinated a Divisional Open House. It was attended by over 2000 visitors and provided the basis for some very positive comments about Ontario Hydro in the Provincial Legislature. The Department also assisted the Director with numerous presentations, senior management meetings, and with initiatives such as the modernization of the auditorium. The Research Division Awards Program is another important way of fostering and rewarding excellence within the Division. The awards program for 1989 was organized by the Department and held at the Airport Marriott Hotel.

The Department continues to provide support in the area of external contracts. Activities included liaison with Law and New Business Ventures Divisions, development of contracts and agreements, development of requests for proposals, and the production and monitoring of information related to financial aspects of contracts.

In support of the Divisional external contract function, the Department provides a monitoring function by scanning external publications for contracting opportunities.

In addition, the Department maintains and updates information on the Division's capabilities in a number of externally-based databases.

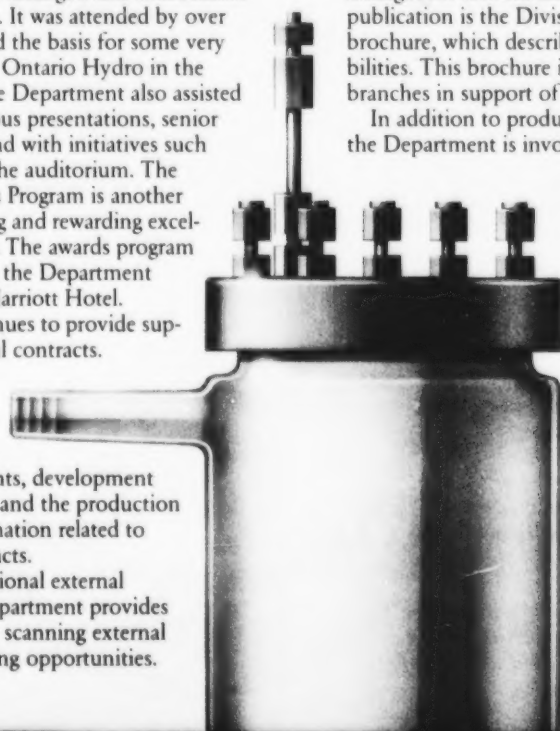
In support of the Division's business activities, the Department assists in the planning and hosting of technical conferences. Examples are the recent meetings of the Canadian Industrial Laser Association, Conference on Large Electrical Systems (CIGRE), the Electrochemical Spring Symposium, and Institute of Electrical and Electronics Engineers (IEEE). Other activities include arranging training sessions for clients of New Business Ventures Division, development and deployment of special displays, and arranging events to promote the Division to external organizations.

The Department is involved in the identification and development of communications. Perhaps the most important of these is the Division's Annual Report, the document you are reading now. The Department assembles the text, coordinates the editorial activities, and arranges for artwork and printing. Another significant publication is the Division's Services and Capabilities brochure, which describes the Division's R&D capabilities. This brochure is used extensively by other branches in support of their marketing activities.

In addition to producing written communications, the Department is involved in the production of videos that describe the activities of the Division.

One such video, for visitors and new staff, has been produced this year, and another, which deals with the contribution of Ontario Hydro and the Research Division to the growth of Ontario, is being planned.

The communications produced by the Department are of a high calibre. They have won a number of awards from organizations that specialize in industrial communications.



DIVISIONAL SERVICES: MANAGER'S OVERVIEW



This year, the Divisional Services Department achieved its objective of providing excellence in service to Ontario Hydro's Research Division. Services were many: those offered included business administration; financial reporting; payroll; records, space, and safety management; printing and clerical services; report production; model shop production; drafting; photography; and editorial services. Additionally, significant strides have been made in the Integrated Computing Environment (ICE) project.

The Model Shop continues to upgrade and strengthen its support capabilities. New equipment and tooling was acquired this year. With higher accuracy as a goal, machines were replaced, numerical control was introduced, and all machine axes were equipped with linear encoders. Accordingly, emphasis was placed on meeting the needs of the Division more efficiently, as well as on meeting some of the more stringent requirements of the Design and Construction Branch, the CANDU Owners Group (COG), Canadian Electrical Association (CEA), Electrical Power Research Institute (EPRI), and Central Production Services Division (CPSD). To date, the prototyping service has made a significant contribution to both the Spacer Location and Repositioning (SLAR) and the Channel Inspection and Gauging Apparatus for Reactors (CIGAR) programs.

The Integrated Computing Environment Section has taken on the responsibility for the delivery of computer communications, technical computing, and voice messaging services. Before ICE could deliver its services to the Research Division, a suitable design was required for the installation of network cabling and electronic components. Finalizing a design was not easy because of the wide variety of tenant needs, the rapidly evolving communications industry, and the electrically noisy environments that exist within many Divisional laboratories. This year, however, a suitable design was finalized and Divisional employees can look forward to devices that will allow their personal computers to be networked with others, both within and outside the Corporation. A voice messaging service means that colleagues can be contacted quickly via an automated telephone-answering service. A wide variety of office automation, data manipulation, and technical problem solving tools will allow larger Divisional business goals to be achieved economically and efficiently. The anticipated benefits

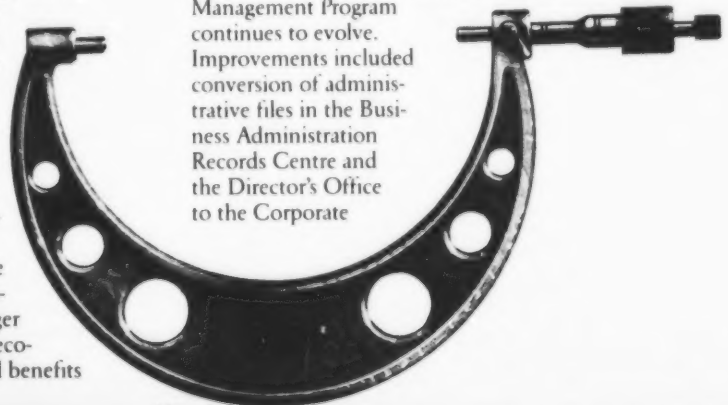
of the ICE initiative are increased productivity plus real financial savings resulting from the ability to share the use of costly computing resources. The payback period on the investment required to install the ICE network is expected to be within twelve to fifteen months of completion, which is scheduled during 1990.

The Drafting Section continues its long-term commitment to deliver the very best in drafting, design, and illustration to Divisional staff. Consistency, precision, and innovation are necessary to produce quality drawings and prompt revisions. Innovation in ways of producing quality designs and illustrative graphics is the hallmark of this Section. Extensive use of Mac II and Autocad systems allows emphasis to be placed on timely accommodation of the Research Division's internal clients. Additionally, the Drafting Section prepares drawings and provides ideas for drafting and design graphics for both the Division and the public. High quality technical illustrations grace the Research Annual, and mural designs improve the decor and work environment of the Division. The Drafting Section's work impacts not only on effective visual communication, but also on morale.

The Photographic Services Section has had another hectic, but successful, year. Video productions ranged from one targeted at the new employee to another promoting the Division's work internationally. "Affirmative Action - Women for the Future", "Fusion Energy" [a World Energy Conference/Canadian Fusion Fuel Technology Program (CFETP) Production], and most recently, "GEMS", Generator Expert Monitoring System, (produced for EPRI) are some other examples of fine video productions.

The Research Publications Office continues to produce the Research Annual, which last year won accolades from many, most notably in the form of a Society for Technical Communication achievement award. "Chit Chat", the Division's informative newsletter, was redesigned and, based on a user survey conducted this year, is playing an important role in enhancing communications and boosting morale. Desktop publishing capabilities now allow the office to play a significant role in the production of the Division's Business Plan. A number of communications courses for staff of the Division were thoroughly investigated by a member of the office staff, and suitable courses were subsequently recommended to the Research Executive. Finally, a report database, which has been under development for some time, is now functional, and plans to transfer it either to the Hydro mainframe or the ICE network have been initiated.

In the Business Administration Section, the Records Management Program continues to evolve. Improvements included conversion of administrative files in the Business Administration Records Centre and the Director's Office to the Corporate





Frank Turone of Research Division's Drafting Section works at a computer terminal. Extensive use of Macintosh II and AutoCAD systems allows timely accommodation of Research Division's clients.

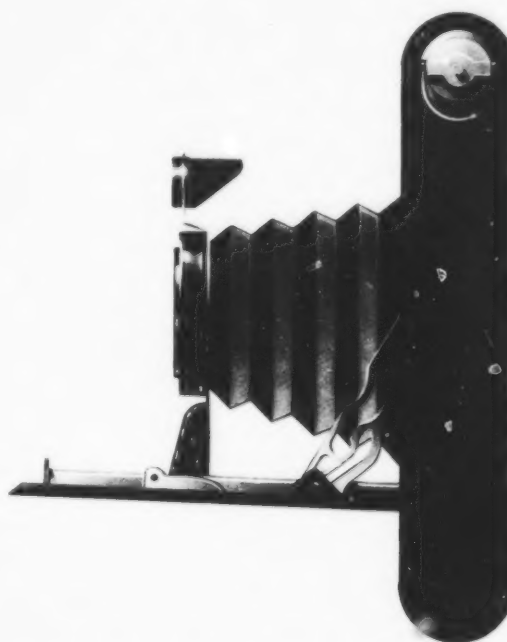
General Subject Index. Additionally, technical files in the Radioactive Materials Laboratory are eighty-five percent converted and expected to be completed by year-end. Approximately forty boxes, i.e., over eighty-three feet of inactive files from central records were reviewed and either marked for destruction, given new retention periods, or identified as having archival value. A presentation was given to key personnel on how to use the revised administrative filing index to its potential. Further presentations are planned before year-end.

Information Management has continued its commitment to provide secretarial and telecommunications support to Research. The Word Processing Centre provides a relief service by filling secretarial positions in the Division. Additionally, short-term clerical and filing help can be provided as required.

The Health and Safety Section ensures that line management provides a healthy and safe work environment. It also provides guidance to the technical sections on environmental matters, such as pertain to laboratory waste disposal, spill control, and releases of airborne substances into the environment.

Legislative pressure and Corporate obligations have raised issues related to hazardous material management. Most departmental effort was directed at ensuring compliance with Workplace Hazardous Materials Information System (WHMIS) legislation. To date, all chemicals in the Division have been inventoried and all laboratories have WHMIS boards and supplier Material Safety Data Sheets (MSDS) in place as well as a set of Divisional workplace labels prepared for containers of chemicals. All Divisional staff have received training, and a video-based training program is being completed for future use.

Another health-related issue pertains to the considerable effort spent on ensuring compliance with the Corporate code of practice on accident and incident reporting. Several incidents with high-to-medium potential for harm were investigated. Other major activities assisted in, or carried out, by the Health and Safety Section are initiation of hazard identification training; respiratory protection training; workplace inspections; and consultations for other Research Division Departments. All in all, a successful and busy year for Divisional Services.



ELECTRICAL RESEARCH: MANAGER'S OVERVIEW

The question of the long-term security of an increasingly complex power system that operates under severe externally-imposed constraints deserves serious attention. This is particularly important when new technologies are needed to meet power system growth requirements.

In 1989, a substantial portion of the Electrical Research Department's efforts was therefore invested in the development of a better understanding of aging and failure mechanisms and in the implementation of new diagnostic techniques and protection systems.

Reliable protection of power system components, such as generators, transformers, and transmission lines, is vital to the provision of a dependable supply of electrical power. The failure or incorrect response of a protection system can result in costly damage to equipment as well as lengthy service interruption and can, in the extreme, lead to catastrophic system failure.

In the past, the desired level of reliability of protection systems was achieved with careful system design that incorporated equipment that had undergone extensive laboratory evaluations to verify its suitability for intended applications. However, higher operating stresses on an expanding power system, coupled with the reality of aging equipment, call for new approaches.

New digital schemes are therefore being investigated to develop "smart" protection systems, which could, among other things, detect weaknesses before actual failure occurs. "Smart" systems can be achieved with current computer technology combined with new fibre optic communication links that are inherently immune to electrical interference. This, in turn, provides the potential to increase the intelligence of a system at discrete locations, thereby allowing "smarter" decisions to be made more rapidly.

Specific activities include evaluation of fibre optic interconnections and the development of digital differential protection for transmission lines. These projects contribute toward an overall scheme for power system integrity control that will, over the next several decades, assist in the maintenance of a reliable power system.

Whereas the above serves to address longer-term objectives, a new standardized approach to implementing protective measures was developed at the initiative of, and in cooperation with, the Protection Design Department. The new technique uses an upgraded Programmable Auxiliary Logic Controller (PALC) and semi-customized Application-Specific Integrated Circuit (ASIC) technology to provide a complete relay protection in a single unit that encompasses both the measurement and logic functions. With this approach, standard hardware and adaptable software can serve many relay functions, including a special turbine protection relay based on the monitoring of frequency and negative sequence current. Most of the 100 new PALCs manufactured to date have been committed for installation.

System protection, no matter how effective, cannot compensate for poor component reliability. Special attention is therefore given to the long-term reliability of Gas-Insulated Switchgear (GIS), for voltages up to 500 kV, which must meet stringent performance standards, since

"Times must research can provide the new technology required to meet tomorrow's technical problems"

Arthur Butler, Manager

even relatively low failure rates may be unacceptable in some locations.

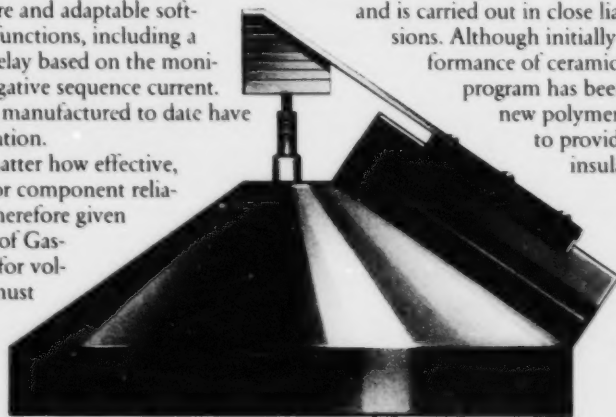
The Research Division, under EPRI sponsorship, and with the support and cooperation of manufacturers, the Technical University of Denmark, and the University of Connecticut, has undertaken a study to gain a fundamental understanding of insulation failure mechanisms, which will lead to a better definition of critical design parameters. An important breakthrough is the development of a vastly improved technique for detecting minute insulation weaknesses that could develop into support insulator failures.

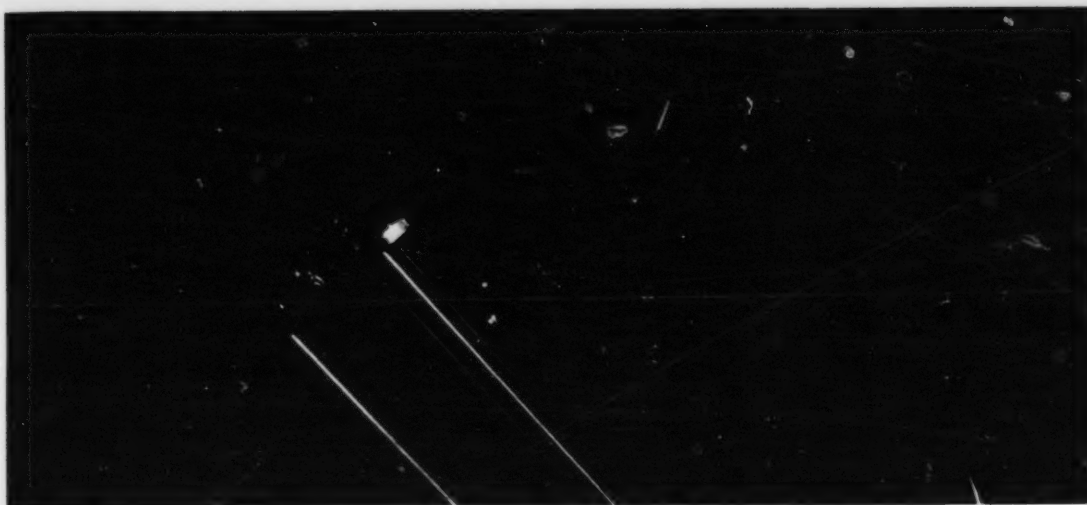
With the emergence of metal-oxide gapless arresters, renewed emphasis on lightning and surge protection has become necessary to secure better performance and to avoid misapplication of future arrester designs. The close cooperation of researchers and manufacturers and their effective participation on national and international technical committees have been essential in working toward the common goal of better over-voltage protection.

As municipal distribution systems are expanded or upgraded to meet increased load densities, concern for long-term reliability assurance becomes acute. These concerns can be addressed most effectively by extensive distribution system component testing and failure analysis. Components tested include surge arresters, fuses, separable connectors, and underground cables. Technology transfer is accomplished through upgraded purchase specifications and active participation in writing industry standards. As a result, these efforts will benefit not only distribution systems in Ontario, but also utilities throughout North America.

An intensive study of the performance of outdoor high-voltage insulation in adverse winter weather continues. This study involves several technical disciplines and is carried out in close liaison with other divisions. Although initially addressing the performance of ceramic insulators, the research program has been extended to include new polymer insulator designs and to provide guidance to polymer insulator manufacturers.

As part of the Department's mandate to provide in-house technical support, special high-power electromagnetic techniques were developed





David Bellamy, technologist, Electrical Research Department, is shown operating a low inventory cryogenic distillation column used for tritium separation.

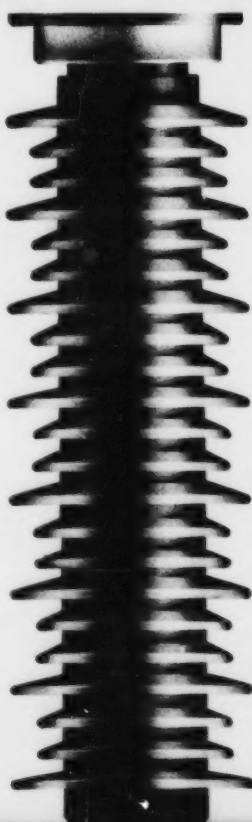
to assist in the assembly and repair of nuclear reactors, the objective being to keep costly downtime to a minimum. Some of these techniques are applicable to energy-efficient industrial processes and, in support of the Corporate objectives, are expected to achieve larger reductions in demand by the year 2000. Whereas substantial reductions can be achieved by simple economic incentives and the application of selected mature technologies, the full potential of economic demand reductions can only be realized if additional benefits are derived from new technologies now under development. With this in mind, the Research Division has implemented a multidisciplinary utilization strategy that relies heavily on liaison with stakeholders and close cooperation with industry. From a corporate viewpoint, this will help ensure that planned demand management investments (i.e., investments in customer-owned equipment to produce power system benefits) will provide the anticipated benefits to Ontario Hydro and the municipal utilities in the province. Past and current industrial support involving electrical processes in manufacturing is wide ranging and includes topics such as electromagnetic aids to steel making, laser welding and cutting, and plasma material processing.

By participating in a 1 000-house survey with Energy Management Branch, Economics Division, and external consultants, the Research Division has helped assess the maximum economic potential for electricity savings in thermal envelope and heating system upgrades in existing dwellings. This evaluation has defined the impact that housing upgrades can have on

the Ontario Hydro system and has provided information for developing demand management programs with realistic targets. Another recent contribution is a newly developed model of energy consumption in single-family dwellings that ensures that utility planners do not overestimate the possible savings from air-sealing and basement re-insulating. Along with this model, better criteria ensure that the upgrades do not adversely affect indoor air quality.

Testing and development work with a Canadian heat pump manufacturer has resulted in the design of an improved hybrid-heating and air-conditioning system that can significantly lower the winter peak demand for electricity in the province. This class of burner-assisted heat pump can potentially save over 100 MW of system peak capacity if installed across Ontario.

Whereas many high-priority research and development activities in the Department are intended to provide a measure of technological assurance for the future, one of the most important considerations in directing a research program of this kind is the ongoing cooperation of many departments across the Corporation. Several of the projects now underway in Electrical Research are the result of initiatives taken elsewhere in Ontario Hydro. Only through the commonly shared objective of "making it happen" can front-line technology meet our high expectations. A well focused and consistent research program with equal emphasis on development and implementation may help to exceed those expectations.



MECHANICAL RESEARCH: MANAGER'S OVERVIEW

"R&D support ensures the structural integrity and reliability of plant equipment and components."

—Gordon J. Glick, Manager

The operation of Ontario Hydro's generation, transmission, and distribution systems must be reliable, safe, support a sustainable environment, and supply electricity to the customer at reasonable cost. The Mechanical Research Department helped the Corporation respond to this challenge in 1989 by its involvement in a wide spectrum of activities, all of which facilitated the implementation of technologies that helped assure the effective future functioning of Ontario's power system.

Ontario Hydro is concerned about the aging and deterioration of its power system components. Some transmission lines have been in service since 1906. To help ensure their maximum reliability, the Research Division is committed to a transmission line refurbishment program. Initial efforts are to establish that towers do have reserve strength and that modern design methods give adequate strength predictions. Hardware and insulators are to be renewed, and overhead ground wires are systematically being replaced. Other activities related to the planning aspects of transmission refurbishment include developing criteria for prioritizing lines for refurbishment on the basis of useful remaining life. Determination of the preferred sequence of refurbishment will be based on these criteria.

This year, a major activity related to the refurbishment effort was the Department's participation in full-scale field testing of transmission towers. Stresses and deflections were measured to determine available levels of reserve strength. This year, 115-kV double circuit McGuigan-type transmission towers, built in 1911 in Oakville, were subjected to testing under various conditions. The results will be of great value in the assessment of older lines and in the development of an economical and technically sound refurbishment program.

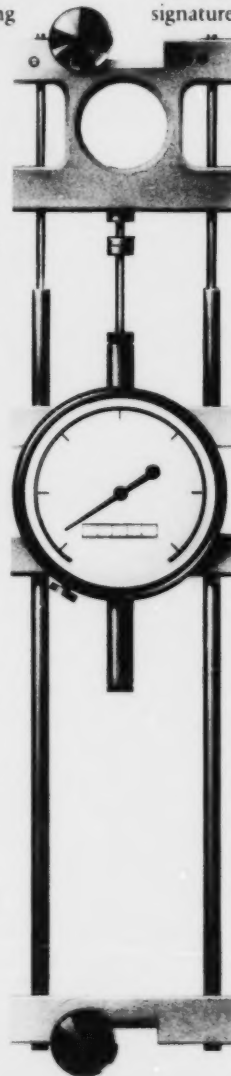
Not only Ontario Hydro's transmission lines are aging, some of Ontario Hydro's generation plant is being refurbished to ensure its continued reliable generation. The Mechanical Research Department is involved in testing hydraulic runners. Results of these tests will contribute to an inventory of information, which will be helpful in the assessment of runner condition, determination of remaining runner life, and the

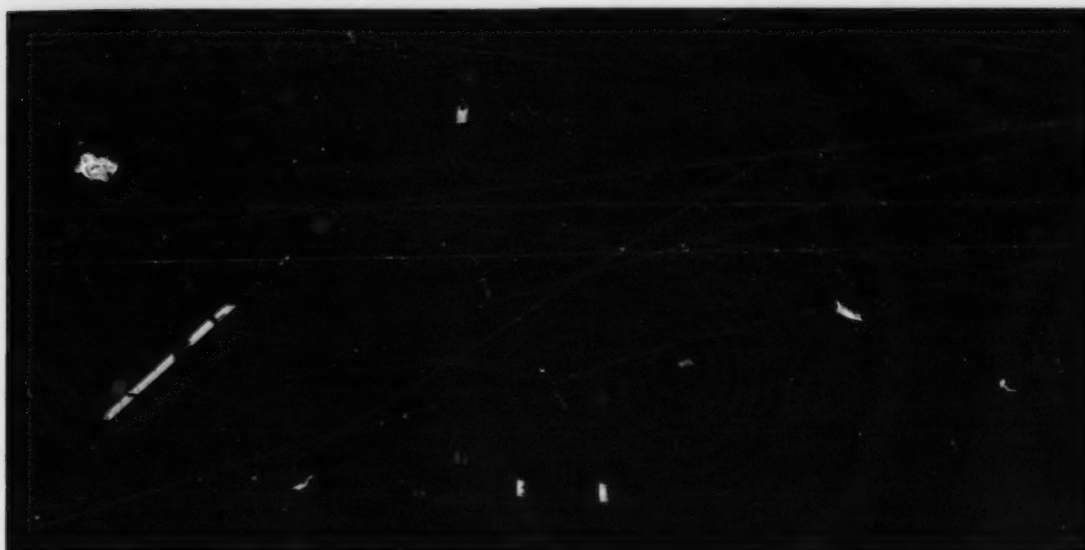
need for runner repair or replacement. To aid this effort, a test rig has been built for the testing of runners removed from generating plant at the end of their operating lives. Runners are to be tested to destruction by subjecting them to the speeds and accelerations they experience during in-service operation.

Other work being done in the Mechanical Research Department relates to the development of equipment condition monitoring systems. Various types of computer-managed rotating-equipment monitoring systems have been developed, and technical assistance has been provided to a number of plants relating to their implementation. The information generated by these systems allows maintenance to be performed on a timely basis only on those components that need it. Avoidance of unnecessary maintenance and timely diagnosis of components requiring unexpected repair means an increase in equipment reliability and the minimization of plant downtime as well as cost. Already, these systems have been instrumental in detecting loose parts (debris, failed components, tools, etc) that, if not removed, would have resulted in significant damage and equipment downtime. The effectiveness and efficiency of monitoring systems is expected to be enhanced even further by the application of research currently being done in advanced signature analysis, neural networks, and expert systems.

The Mechanical Research Department plays a leading role in coordinating the Research Department's contribution to developing methods to deal with the containment and immobilization of irradiated fuel and safe methods of storage, transportation, and ultimate disposal of high- and low-level nuclear wastes. Currently under development are a tritiated heavy water transportation package, a cask for transporting irradiated fuel, and other specialized containers. Experimental impact tests and extensive finite element analysis have demonstrated the impact resistance of the transportation package. On the strength of this work, a transportation licence has been obtained from the Atomic Energy Control Board.

Study continues on the analysis of hydride blister formation in Canadian Deuterium Uranium (CANDU) reactor pressure tubes. Mathematical models are being developed to predict hydrogen transport and blister growth and to predict the useful life of pressure tubes under a variety of conditions. Another pressure-tube-related study involves the development of a computerized program that can predict the degree of degradation occurring in pressure tubes due to creep. Data generated by this program can then be compared to data obtained through in-reactor measurement. Studies are also being carried out to determine whether or not it is creep deformation that is responsible for allowing pressure tubes and calandria tubes to come into contact. Yet another pressure-tube-related study is attempting to determine the effect of fretting on the performance and useful life of pressure tubes and calandria tubes. The





Tests to study the structural integrity and foundation of transmission towers are being carried out on McGuigan-type towers in Oakville, Ontario, as part of the transmission line refurbishment program.

goal of this particular study is the development of a methodological procedure for predicting long-term fretting behaviour using short-term data. Results will provide the necessary tools for identifying vulnerable tubes and for assessing the possibility of life extension.

The Spacer Locating and Repositioning tooling has been redesigned as a response to high wear rates and high friction coefficients of bearing materials in the current design. At the request of AECL, Mechanical Research evaluated the tribological characteristics of a number of selected materials under simulated operating conditions. A database of wear rates and friction coefficients was produced, and based on it, the materials that best met the SLAR redesign requirements were selected.

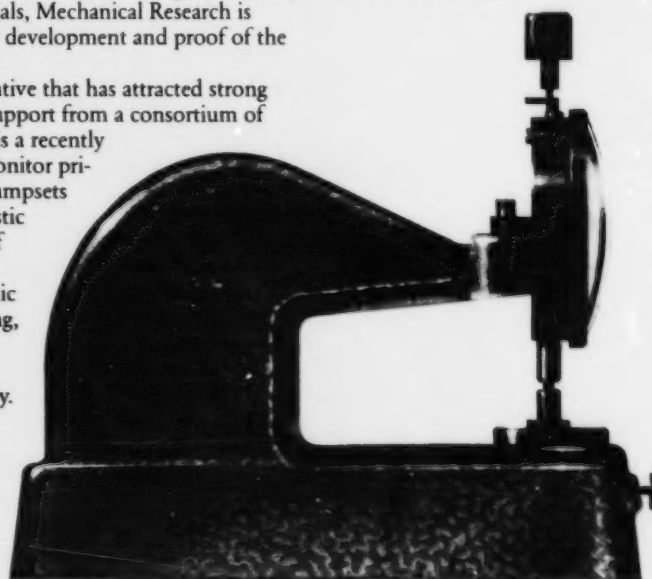
There is great economic incentive to operate nuclear power units at the maximum output permissible within the licensed limit of reactor power. Reactor power output is determined from an overall plant heat balance, which, in turn, depends on feedwater flow. Thus the accurate measurement of feedwater is important. To check the calibration of in situ plant instrumentation, a non-intrusive flow meter is used. Through laboratory calibration and field trials, Mechanical Research is contributing to further development and proof of the instrument's efficacy.

Another major initiative that has attracted strong interest and funding support from a consortium of international partners is a recently launched project to monitor primary heat transport pumpsets by vibration and acoustic methods. The scope of the project embraces comprehensive dynamic analysis, baseline testing, and fault-simulation tests on a full-scale pumpset in a laboratory.

The recruitment of women to non-traditional jobs is a Corporate objective.

The Department actively participates in the process. Participation is not only limited to offering on-the-job training via developmental rotations, but also to doing work to make equipment suitable for operation by female staff. As part of a fall protection program, a project is underway to design fall protection equipment for the special needs of women. The work is being done in collaboration with the Faculty of Medicine at the University of Toronto. A prototype, fall-protective device is under development and will be tested based on injury threshold and endurance limits for women when exposed to the types of impacts experienced during the arrest of a fall.

What has been described above is only part of the Mechanical Research Department's contribution towards safeguarding the Corporation's enormous capital investment in equipment, components, and in human resources. The objective of this is to ensure that Ontario Hydro's generation, distribution, and transmission systems are reliable, safe, support a sustainable environment, and supply electricity to the customer at reasonable cost.



METALLURGICAL RESEARCH: MANAGER'S OVERVIEW

The Metallurgical Research Department provides research and development, technical services, and specialized testing facilities in the disciplines of physical and process metallurgy and materials science. The overall thrust of these activities is to ensure a safe and reliable supply of electrical energy and to improve the efficiency of its utilization. In pursuit of these goals, the Department deals with characteristics of materials' performance and with correlation of both design intent and actual service behaviour.

The majority of the Metallurgical Research Department's work program is focused to support CANDU technology. Analytical and test techniques have been designed to investigate the factors that control the deformation and fracture of zirconium-niobium pressure tubes; it is these that make up the core of a CANDU reactor. An important part of the Department's studies is to achieve end-of-life conditions in tube specimens far in advance of actual in-service components. This is achieved by testing in high-neutron flux reactors, such as in the DIDO reactor in the U.K. Work has been ongoing in this reactor for several years, samples there being close, in terms of total fluence, to material in those Hydro reactors with the longest operating lives. Even better facilities are now available in the OSIRIS reactor in France, where experiments began this year. Resulting data will provide input useful in developing design equations and, additionally, in establishing the effect of irradiation on the microstructure of pressure tube alloys. Transmission electron microscopy studies of irradiated material are being carried out, both in the Department and at the University of Cambridge in the U.K.

Crack nucleation and growth are studied using samples of pressure tube material where hydrogen concentrations have been increased to end-of-life levels; particular emphasis is on the formation and growth of hydride blisters as precursors to crack initiation. A pressure tube burst rig is fully operational and supported by flaw evaluations, which utilize techniques of elastic-plastic fracture mechanics. An additional test rig has been developed to conduct corrosion fatigue tests of zirconium-niobium in primary heat transport water.

Most corrosion-related studies are focused on establishing a detailed understanding of the principal source and ingress route of deuterium into the pressure tubes. This year saw the application of secondary ion mass spectroscopy and transmission electron microscopy to examination of the interface between oxide and metal. The critical nature of the oxide layer as the deuterium-ingress controlling feature, from both the water and annulus gas sides of the pressure tube, was confirmed.

The accurate measurement of hydrogen/deuterium in irradiated pressure tubes has received a great deal of attention this year. A nondestructive evaluation (NDE) technique that uses resistivity changes in materials as a function of hydrogen concentration was successfully demonstrated. Other advances in the NDE area included the development of laser thermography to measure annulus gas flow, a technique that is described in detail in the earlier article, "Safeguarding Corporate Investment: Research and Development as Technological Insurance." Also, new pressure tube scanning software developed in the Department was used in



inspections of Unit 3 of Bruce NGS and Unit 6 of the Pickering NGS. This software permits imaging of defects in such a manner as to allow for better estimates of radial depths.

Progress continued in the area of digital signal processing. Deconvolution techniques were used to improve eddy current gap measurements. Blister crack depth measurements obtained by ultrasonics were optimized by synthetic aperture focusing and filtering. Additionally, filtering, windowing, and normalizing of high frequency spectra were used to measure pressure tube oxide thickness.

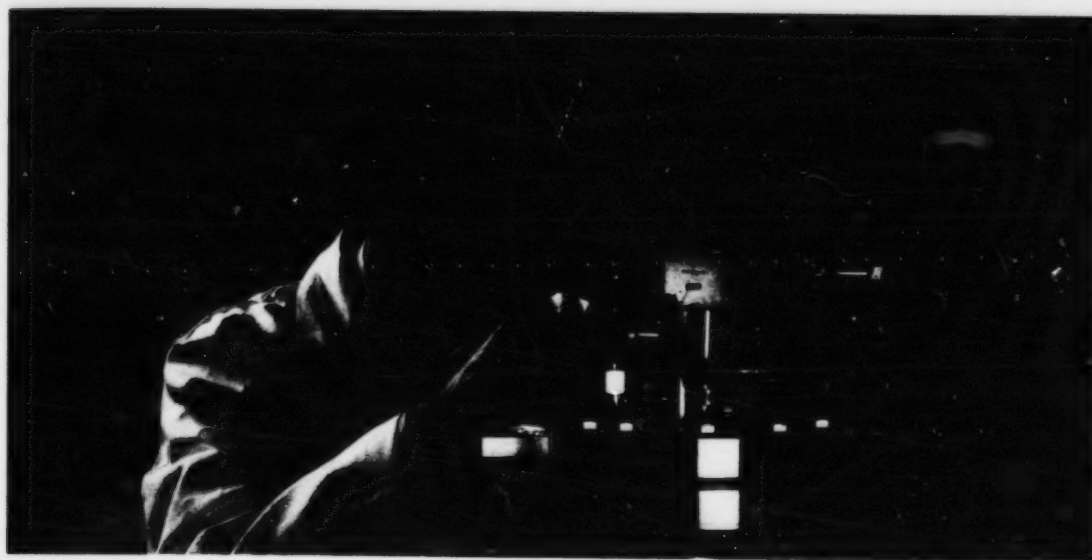
Although the Department is heavily committed to fuel channel research, other components of nuclear generating plant are receiving attention. Laboratory data have implicated a microbiological component in the corrosion of lakewater-cooled heat exchangers. This may have important repercussions for many nuclear, thermal, and hydraulic systems. Sampling and testing by means of microbiological techniques is being supported by advanced surface analysis techniques in an effort to determine the impact of microbiological processes on the corrosion. The expertise developed will be vital in minimizing the impact of zebra mussels on station systems.

In 1989, the Darlington NGS heat transport system leak-before-break project was completed. This included extensive elastic-plastic fracture mechanics calculations, computer code development for fatigue analysis, and fracture toughness testing of pipe welds and elbows.

Many departmental resources are directed of necessity toward assuring the reliability of Ontario Hydro's nuclear plants. However, support is also provided to conventional coal-burning units. Support is focused particularly in the area of life extension. A great deal of effort was put into helping Lakeview TGS manage the consequences of weldment creep cracking on one of its main steam lines. This included the initial emergency failure analysis and a comprehensive follow-up of the failure mode. The Department played a major part in the subsequent assessment of the integrity of all high-energy pipe weldments in the plant.

In August, a field test of the robotic system for hydraulic turbine cavitation repair was carried out. During a week and a half at Hydro Québec's Carillon GS, an impressive demonstration of the system's reliability and capability was achieved.





Andy Heics of Metallurgical Research Department is examining a tritium storage bed designed at the Research Division. These beds will be used at West Germany's Karlsruhe Nuclear Research Centre's Tritium Laboratory for the temporary storage of tritium.

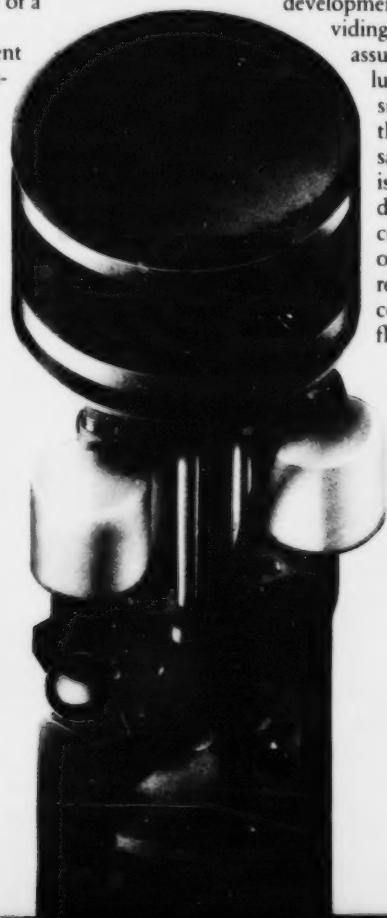
Although the objectives of the CEA-supported development project have now been attained, continued cooperation with the Institut Recherche Electricité de Québec (IREQ) is envisaged to develop the capability further.

In the transmission major program area, the Department, in collaboration with an external commercial laboratory, won a large CEA contract to develop the application of modern fracture mechanics to assure the integrity of transmission line hardware. Effort in this program area is supplemented by a study of the use of advanced materials in the manufacture of a variety of components.

Not all of the work of the Department is directed toward ensuring reliable supply. The tritium laboratory is now almost fully commissioned with multiple work stations and a modified tritium storage and delivery system. A prototype solid, metal-matrix tritium light has been successfully demonstrated. Although, at present, the light is of low intensity, the concept is considered to have a great deal of commercial potential.

Finally, in support of demand management objectives, an electric-arc furnace was built and commissioned. The furnace is to be used to examine ways of increasing the efficiency of the metallurgical and materials processing industry. Metals producers, who are some of Ontario Hydro's most important customers, have shown great interest in the facility, and a cooperative project with Falconbridge Limited is already underway.

The Metallurgical Research Department considers itself to be carrying out a successful research and development program primarily aimed at providing the Corporation with "technological assurance" in the disciplines of metallurgy and materials science. By necessity, the program is focused to ensure the reliability of supply while, at the same time, recognition is given to issues that impact on economic and demand management. Innovations continue to be made in a number of areas with the goal of solving current problems, forestalling future concerns, and providing long-term flexibility.



OPERATIONS RESEARCH: MANAGER'S OVERVIEW

The Operations Research (OR) Department provides applied research and support to the Corporation when unusual and complex operational and strategic problems arise.

Problems run the gamut from those related to management systems and procedures, through those concerning data and information handling, to problems related to equipment and materials. Solving these types of problems requires a full range of state-of-the-art mathematical and computational methodologies.

In 1989, the client base and the range of services continued to expand in the areas of decision and operational analysis, statistical analysis, probabilistic analysis, and power system reliability modelling. Services varied from informal consultations and short presentations to large-scale projects and tailor-made courses and seminars. Specialized computer applications services were provided to Divisional staff. The Department is one of the most active and effective industrial OR groups in North America.

"A concerted team effort enhances management effectiveness and operational efficiency."

Yuhui Chang, Manager

Although most OR techniques were developed during and after World War II, they are now widely used in business, industry, and government to enhance management effectiveness and operational efficiency.

Traditional techniques such as linear programming, inventory control, and queuing theory have always been important to management studies and, as OR methods have started to merge with information technology, have become essential components of decision support systems. Current interest in the measurement of intangibles and in complex decision processes provides an additional challenge. Problems often involve multiple and conflicting objectives, solutions not being always apparent. Researchers, however, are sensitive to decision environments and able to develop innovative approaches to decision analysis.

After achieving a high degree of diversification over the last few years, this year the departmental team focused its efforts on projects with the potential to contribute to enhancements in strategic planning or operating efficiency. Services were provided to a number of Branches, which included Production, Regions, Finance, and Supply and Services. An example of this effort is the development of a manpower planning model for electrical inspection. This model will be used by all regions in Ontario Hydro and will enable manpower requirements to be determined more accurately. An example

of an efficiency improvement project is the application of optimization techniques to hydraulic generation. The computerized optimization model is expected to improve station operating decision-making and reduce judgemental error, which, in turn, may result in substantial savings.

Since a reliable supply of electrical energy is part of Hydro's mandate, accurate reliability predictions for power systems and their constituent parts is a most important engineering task. Equally critical is the assessment of risk involved in many operating situations. The development of reliability methodology based on probabilistic modelling has come a long way in the last 25 years, but the methodology is still not mature enough for use in all applications. The Department's reliability team, however, is at the forefront of the worldwide effort to develop more advanced reliability tools.

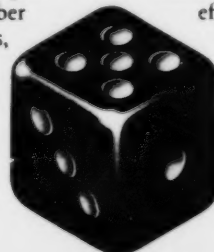
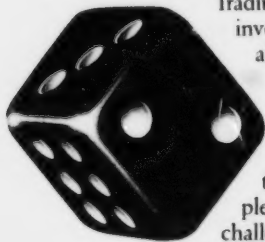
The team's involvement with the development and application of mathematical models for system and component reliability spans almost two decades. The objective has been to assist the Corporation's planning, operating, design, and maintenance functions. In 1989, the reliability team engaged in developmental work and provided technical assistance to other Divisions. Important progress has been made in the optimization of maintenance procedures and the development of new concepts and modelling techniques, which were introduced to represent the processes of deterioration and failure. The reliability evaluation of the control and operating facilities for the new System Control Centre at Clarkson was completed with a report and a presentation to client and users.

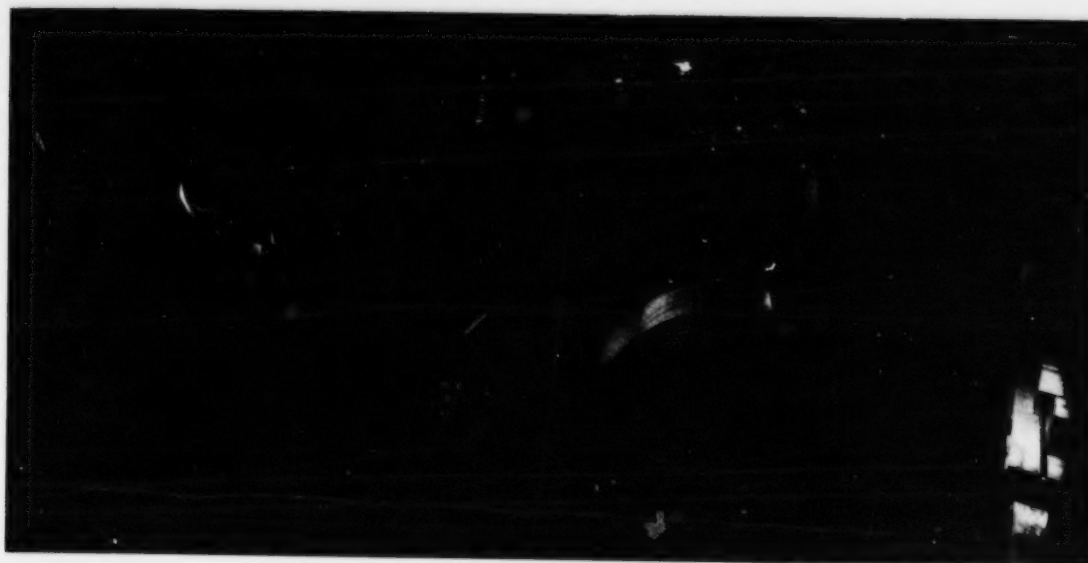
Through publications and participation on committees and in conferences, the reliability team's international reputation was enhanced. This year, staff were involved in a number of international technical activities, including participation in a working group at CIGRE. The team continues to be involved in industrial advisory activities for several EPRI research projects, and it has delivered seminars on power system reliability analysis in Canada, the United States, and in Hungary.

The selection and analysis of data for technical or management studies often appear straightforward. However, when data are scarce, interrelated, dispersed, or even contradictory, the drawing of valid conclusions requires advanced statistical analysis. Assistance in solving statistical problems is provided by the statistics team. The team's expertise includes knowledge of sampling schemes, statistical estimation, experimental design, forecasting, regression analysis, probability theory, mathematical modelling, quality control, and quality assurance.

In 1989, the team performed a number of studies for other Divisions as well as for the Research Division. Studies included the development of a forecasting method for the Niagara River flows; the development of techniques capable of detecting temporal shifts in climate at the regional level due to the Greenhouse effect; the estimation, from the observed

temperature profile, of the rate of gas flow through the annuli around pressure tubes; and the determination of the impact of converting M&P salary ratings to Hay system ratings. In addition, members of the team participated in the working party on the environmental and





Dennis Gonsheff of Operations Research Department discusses with Harry Mewes of Supply Division how a recently developed forecasting model can be used to set reorder points for materials in the stores inventory.

safety research assessment of the CANDU Owners Group Waste Management Program. Assisting clients through informal consultations continues to be an important part of the team's activities.

In recent years, rapid advancement in computer technology has provided the computer support team with new challenges. In 1989, apart from the internal specialized service function, emphasis was placed on the adaptation of new computer technology to solve engineering and scientific problems. Examples are the development of an environmental database, signal processing, and computer communication.

The advancement in computer and information technology has created opportunities of strategic importance to Ontario Hydro's effective and efficient operation. Among them are artificial intelligence and database technology. In 1989, the Department was engaged in the successful development of prototype expert systems. Identification of high payback opportunities continues. Work is being done on estimating the errors associated with computer vision, which at this time is limited. The work will be important in the robotics area.

Neural network technology continues to expand the pattern recognition capability of computer systems. With rapid developments in these fields, special applications in robotics, pattern recognition, and knowledge preservation and distribution are anticipated in the near future.

The Department continues to be involved in external

activities with universities, professional associations, and research institutes. A number of staff members held adjunct professorships or served as executives or committee members with professional societies or research granting agencies. Informal collaborative research arrangements were made with universities. Internships were offered to the University of Strathclyde in Scotland. Staff were also invited to make technical presentations at various universities and to industries world-wide.



RESOURCES AND COSTS

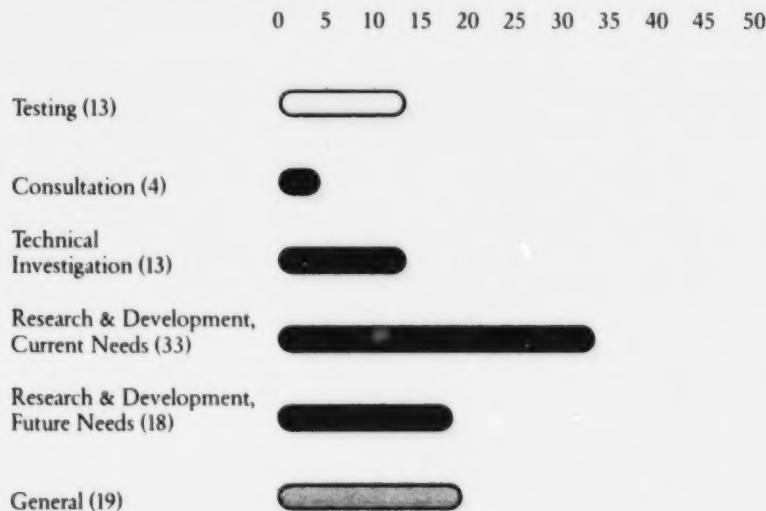
At the end of 1989, the Division's personnel resources consisted of a total regular staff of 633. The percentages of funds allocated to major work programs and the percentages of program costs attributable to OM&A – the net cost to Ontario Hydro to operate, maintain, and administer the Research Division – are shown below. Also shown are the application of staff in various categories of work (Divisional Services Department excepted), and the distribution of staff in broad occupational classes.

The total of all costs, including those for space, materials, and equipment, for work done by the Research Division in 1989 was approximately \$74.2 million.

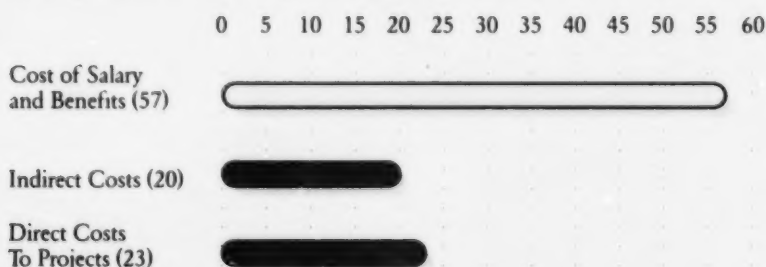
Costs were met or allocated as follows:

Revenue from work done for other organizations	3.9 M
Transfers to other Ontario Hydro Branches	36.8 M
Transfers to the Cost of Power	33.5 M

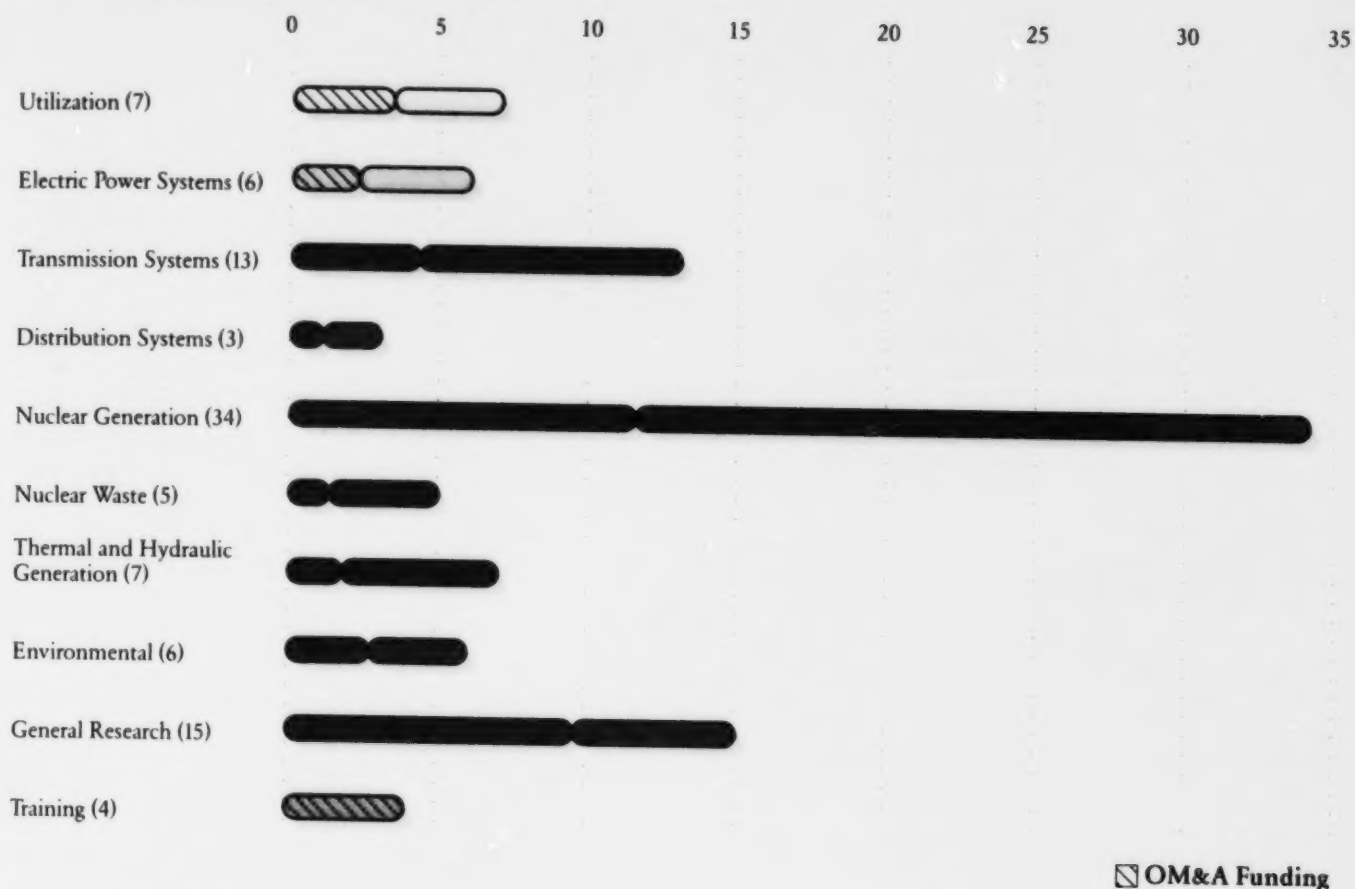
Proportions of Research Division Costs for Various Categories of Work



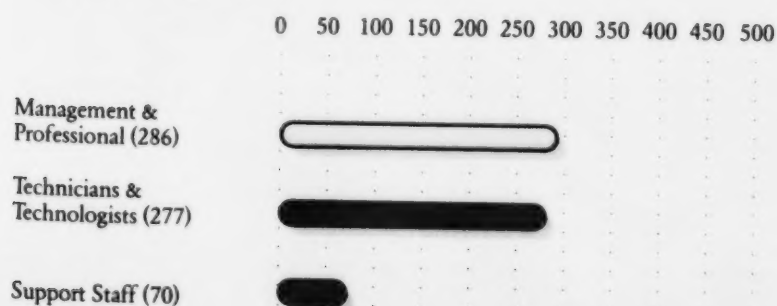
Research Cost Breakdown by Major Resource Categories (% of Gross Costs)



**Research Division Programs:
Proportions by Actual Gross Costs for 1989**



**Occupational Classification of
Research Division Staff**



AWARDS AND ACHIEVEMENTS

"A Discharge-Locating Probe for Rotating Machines," a research paper co-authored by Howard Sedding and Greg Stone (Electrical Research), was chosen from among 115 others presented at the Chicago '89 Electrical Electronics Insulation Conference/International Coil Winding Association Exposition to be awarded the \$1,000 grand prize. The probe described in the paper was developed by OHRD, and through the use of a capacitive sensor that can detect radio frequency stator emissions, it solves the problem of partial discharge location.

Hugh Morrison (Electrical Research) has been awarded a prestigious research fellowship from the Science and Technology Agency of Japan to work in the national laboratory, the Institute of Physical and Chemical Research (RIKEN). The Hydro researcher, who in January 1990 began working on laser isotope separation with Kazuo Takeuchi of the Laser Science Group, was one of only five candidates selected from Canada for the fellowship.

For the first time in its history, the American Society of Mechanical Engineers (ASME) has presented the ASME Blackall Award to a Canadian team. Helmi Attia (Mechanical Research) is this year's recipient for leading-edge research on nonlinear thermoelastic behaviour of structural joints, a research project that extended over 10 years and resulted in the publication of more than 15 papers in refereed journals.

Steve Oda (Electrical Research) was appointed to the Board of Directors of the Industrial, Scientific, Medical, and Instrumentation (ISMI) Section of the International Microwave Power Institute (IMPI), which is headquartered in the United States. Steve Oda's appointment is the result of Utilization Section's involvement with the application of microwaves for industrial material processing, particularly in the area of ceramics.

The quality of publications produced in the Divisional Projects Department continues to attract the attention of the Society for Technical Communications (STC). This year the Services and Capabilities brochure won the prestigious Distinguished Award, the 1989 Research Annual and Chit Chat won awards of excellence for writing and design, and the series of bookmarks, "Hydrolines" was also recognized by an Award of Achievement. The STC is the world's largest professional organization devoted to the arts and sciences of technical communication.

Scott Lawson (Metallurgical Research) was awarded the Welding Institute of Canada's annual Robert J. Jacobson Memorial Award for his contribution to the operation of a local Chapter. Scott Lawson was an executive member of the Toronto Chapter of the Welding Institute from 1978 to 1988. Additionally, he served as Chapter chairman during the years 1980 and 1981.

For the fourth consecutive year, Holly Anderson (Mechanical Research) has been appointed to the national executive of Women in Science and Engineering/la Corporation des Femmes en Sciences et en Génie (WISE/CFSG), this year as national co-director. The nonprofit organization encourages women to enter careers in science, engineering, mathematics, and computer sciences by providing speakers for career

guidance sessions at local schools and by organizing conferences for female students. WISE/CFSG also serves as an information centre for and about women in these professional fields, thereby helping Canadian women to attain high levels of professional achievement.

Early in 1990, PRECARN Associates Inc. will embark on a \$28 million research program. In anticipation thereof, its Board of Directors approved four recently completed feasibility studies, one of which was submitted by the Research Division. Bruce Nickerson (Electrical Research) was the lead applicant for funding of a project that concerns active vision navigation of a mobile robot in a known environment. Federal government and private sector financial assistance are also expected to be confirmed for this project.

Soon-Hok Sim (Operations Research) has been appointed as a member of the Industrial Engineering Chairman's Advisory Board at the University of Toronto. The appointment involves assisting the Department of Industrial Engineering to maximize the quality of its curriculum, increasing the amount of research and development work conducted by the department, and promoting and increasing employment opportunities for the department's graduates and undergraduates.

Staff at OHRD have, over the past two years, organized the Canadian Industrial Laser Association (CILA), which acts as a national body to (1) provide an unbiased source of laser technology information and (2) bring together new and experienced laser users. The development of this association will increase acceptance of laser technology and contribute to the Research Division's effort to transfer energy efficient electro-technologies to Canadian industry. The inaugural meeting of CILA was held in March 1989 under the chairmanship of Jim O'Neill (Electrical Research), and was attended by approximately 100 people representing government, industry, and academia.

Nineteen eighty-nine marked the first year that Ontario Hydro President and CEO Robert Franklin recognized the development of new technology for Hydro in the form of the first annual New Technology Awards. John Deans and Joseph Vitanyi (Civil Research), along with Joseph Phillips of Transmission Programs Group, shared a \$10,000 New Technology Award for solving the problem of winter-time transmission line construction and repair. The newly developed very low-temperature polymer concrete can be placed without the need for costly and time-consuming heating and housing during the curing process. The concrete technology is expected to save the construction industry tens of millions of dollars.

The Stable Isotope Research (SIR) program is a five-year joint effort between Ontario Hydro's Research and New Business Ventures Divisions. Created to develop and bring to market new isotope technologies, materials, and applications, the SIR program is especially interested in collaborating with business, industry, and academic researchers to meet its objectives. Dennis Mullins (Chemical Research) and Jeffrey Robins (Electrical Research) are co-organizing work in the Research Division that currently focuses on the stable isotopes of hydrogen, carbon, oxygen, and nitrogen.



From left to right: Robert Franklin, President and CEO of Ontario Hydro; John Deans, Joe Phillips, and Joe Vitanyi, prize-winners; and Ray Brown, Director of Design and Development - Transmission. Prize winners received a shared \$10,000 award for their role in the development of a polymer-based concrete that properly cures at temperatures as low as -25°C .

The 1988 Research Division W.P. Dobson Award was presented to John Janis (Chemical Research) for his development of a PCB dechlorination process. His technology was approved by the government in 1987 and is currently utilized by private industry throughout Ontario, Quebec, and the Maritime provinces.

Since 1985, the H.A. Smith Award has been offered for outstanding contributions that have had a major impact on the business of the Research Division. Nineteen eighty-eight recipient Andrew Sulowski (Mechanical Research), recognized for his research in the field of fall protection, has earned an international reputation for his extensive, leading-edge work. His new fall arresting system has prevented at least four potentially fatal accidents, and there has been no fatality attributable to a fall since his system was implemented in 1984.

Steve Campbell (Electrical Research) earned a 1988 Research Division Director's Award for technical competence and service above and beyond the call. Steve Campbell developed a breakthrough technology for extracting diagnostic signals from operating turbogenerators.

Craig Simpson (Divisional Projects) was recognized with a 1988 Research Division Director's Award for his role in the research and development of new industrial electrotechnologies. His efforts were invaluable in the establishment of both the Process Metallurgy Group and the Lakeview Plasma Facility.

Carolyn Ashby and Chuck Blacklock (Divisional Services) were recognized with a 1988 Research Division Director's Award for their creation of an innovative mural in the Nondestructive Evaluation Laboratory. The mural, which enlivens the laboratory workspace, has been such an overwhelming success that similar projects are planned in the Division.

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ACRONYMS

AECB	Atomic Energy Control Board	OCMR	Ontario Centre for Materials Research
AECL	Atomic Energy of Canada Limited	OHRD	Ontario Hydro Research Division
ASIC	Application Specific Integrated Circuit	OR	Operations Research
ASME	American Society of Mechanical Engineers	PALC	Programmable Auxiliary Logic Controller
CANDECON	CANDU Decontamination	R&D	Research and Development
CANDU	Canadian Deuterium Uranium (reactor)	RIKEN	Institute of Physical and Chemical Research
CEA	Canadian Electrical Association	SIR	Stable Isotope Research
CFFTP	Canadian Fusion Fuel Technology Program	SLAR	Spacer Location and Repositioning
CIGAR	Channel Inspection and Gauging Apparatus for Reactors	SRB	Sulphate-Reducing Bacteria
CIGRE	International Conference on Large Electrical Systems	STC	Society for Technical Communication
CILA	Canadian Industrial Laser Association	TGS	Thermal Generating Station
COG	CANDU Owners Group	URL	Underground Research Laboratory
CPSD	Central Production Services Division	WHMIS	Workplace Hazardous Materials Information System
CUICAC	Canadian University - Industry Council for Advanced Ceramics	WISE/CFSG	Women in Science and Engineering/ la Corporation des Femmes en Sciences et en Génie
EPRI	Electrical Power Research Institute		
GEMS	Generator Expert Monitoring System		
GIS	Gas-Insulated Switchgear		
GS	Generating Station		
ICE	Integrated Computing Environment		
IEEE	Institute of Electrical and Electronics Engineers (usa)		
IMPI	International Microwave Power Institute		
IREQ	Institut Recherche Electricité de Québec		
ISMI	Industrial, Scientific, Medical, and Instrumentation (Section)		
MSDSs	Material Safety Data Sheets		
NDE	Nondestructive Evaluation		
NGS	Nuclear Generating Station		
NPD	Nuclear Power Demonstration (unit)		
NPLA	Nuclear Plant Life Assurance		
NSERC	Natural Sciences and Engineering Research Council		

SIGNIFICANT RESEARCH CONTRIBUTION

ANNULUS GAS CARBON-14 REMOVAL SYSTEM AND OXYGEN ADDITION SYSTEM

*From left to right:
Chris Cheh,
Frank Greening, and
Ron Massey.
Chris Cheh holds a
sample of commercially available
calcium oxide, which
is used to prepare the
calcium hydroxide
essential to the
carbon-14 removal
process.*



In CANDU reactors, carbon-14 (^{14}C) is produced primarily in the moderator cover gas system and in the nitrogen annulus gas system. Carbon-14 has been identified as a potential health hazard, attributable to both the ease with which it may be assimilated into the biosphere and its long half-life of 5730 years. Without a removal process, gaseous ^{14}C is eventually released into the environment during pressure relief venting and purging operations. In anticipation of regulations requiring further reduction in ^{14}C emissions, a research and development ^{14}C control and removal program was initiated by the Chemical Research Department over a decade ago.

Prior to the research effort at OHRD, three methods of removing carbon dioxide from gas existed, all of which were disadvantageous or hazardous. In the course of their research, Chris Cheh and Roger Glass discovered that the solid calcium hydroxide system for removing carbon dioxide from gas, previously considered undesirable because it necessitated operation at temperatures approaching 450°C , was effective even at ambient temperatures if the humidity of the gas were raised. This solution to the high-temperature problem constituted an initial breakthrough that led to a series of other findings, ultimately ending in 1989 with the installation of the Annulus Gas Carbon-14 Removal System and Oxygen Addition System at Pickering NGs Units 3 and 4.

The ambient temperature process, which uses calcium hydroxide as the sorbent to remove radioactive carbon dioxide ($^{14}\text{CO}_2$) from gaseous streams, is a safe, simple, and reliable method. It was first tested in actual plant conditions at the Nuclear Power Demonstration (NPD) unit. The ^{14}C removal system used in the moderator cover gas system at NPD was designed and built at

Research Division by Shinn-Der Chang, Chris Cheh, and Rick Currie. It operated for approximately 600 hours before its return to OHRD upon the shutdown of NPD.

After an in-house evaluation of the NPD system, the research team concluded that, with only minor modifications, the system could be used to solve another ^{14}C problem that had surfaced at Pickering: Decontamination of the annulus gas system took on unprecedented importance in 1985 when, during major retubing operations in Units 1 and 2, work was impeded by the unexpected finding of contamination from ^{14}C in the form of an easily dispersed fine black dust. Chris Cheh and Pat Marchione undertook to adapt the system to meet the new needs of Pickering's annulus gas system.

The investigative work of Frank Greening on the nature of the ^{14}C deposit in Pickering Units 1 and 2 directly influenced the decision to add oxygen to the annulus gas system to oxidize ^{14}C to $^{14}\text{CO}_2$. Addition of oxygen facilitates the removal of ^{14}C , with a concomitant benefit of the process being the maintenance of a protective oxide layer on the pressure tubes. Monitoring of the progress of the oxidation and ^{14}C removal was carried out by Analytical Services staff, namely Ron Massey, Ivan Hunter, Peter Agg, Don Oberding, and Wojciech Schmidt.

On July 26, 1989, the Annulus Gas Carbon-14 Removal System and Oxygen Addition System at Pickering Unit 4 were declared in service. Similar systems at Unit 3 had been operating for months. The successful implementation of this technology marked the culmination of many years' research and development and has earned the members of the Chemical Research team deserved recognition throughout the Corporation.